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Anatomy of *Simulium vittatum.*

BY H. B. HUNGERFORD.

(Submitted in partial fulfillment of the requirements for the degree of master of arts.)

Plates XLIII-XLV.

ACKNOWLEDGMENTS.

THE preparation of this paper was undertaken in connection with the experimental work upon the sand fly and pellagra being carried on by Professor Hunter of the University of Kansas.

The anatomical studies were taken up at the suggestion of Professor Hunter, and the writer desires herewith to express his appreciation to him for his kindly interest and helpful suggestions during the progress of the work.

He also wishes to acknowledge the aid given him by Mr. F. X. Williams in reviewing and correcting the manuscript, by Miss Ruby Hosford in loaning material for sectional study, and by Mr. W. T. Emery in collecting and preserving material for the work.

ANATOMY OF *SIMULIUM VITTATUM.*

INTRODUCTION.

The recent widespread interest in the sand fly as the possible carrier of the disease "pellagra" has given the writer a desire to know something of the anatomy and histology of the form common in Kansas, namely *Simulium vittatum.*

The study of the gross structures of *Simulium* has been of some scientific interest aside from its possible connection with pellagra, for, so far as the writer has been able to find, no

morphological study of the adult has been made with the exception of one paper by F. H. Taylor, 1902, on the "Tracheal System of *Simulium*," and studies of the mouth structures by Smith, Meinert and MacCloskie.

A number of writers have studied the larvæ and pupæ in connection with some general problems dealing with a group of related forms. Thus Osten Sachen, '70, made a study of the transformations of *Simulium* species, and Packard, '72, in his "Embryological Studies on Hexapodous Insects" studied the development of *Simulium*. Kellogg and Vaney (1901) used the *Simulium* along with Chironomids and like forms in their study of "Phagocytosis in the Postembryonic Development of Diptera." Vaney (1902) continuing his studies of the fat bodies examined sand flies and other inferior Diptera as he calls them (Culex, Chironomids, etc.). Weismann in studying imaginal buds referred to *S. sericea*, and Miall (1900) in his researches on the respiratory appendages of pupæ figures a *Simulium* sp. Headlee, '06, made a study of the blood gills of the larva of *S. pictipes*, and Dutt in an unpublished article at Cornell recorded his work upon the silk glands of *Simulium* larvæ. So scattered and fragmentary has been the morphological work upon this important insect pest that it has been the desire of the writer to make a careful study of this form in all its stages. However, it is the purpose of this paper to present but briefly the more salient facts regarding the anatomy of the adult female fly.

TAXONOMIC POSITION AND DESCRIPTION OF FORM STUDIED.

Simulium vittatum is a small, compactly built fly belonging to the family "Simuliidæ."

The Simuliidæ are known in the vernacular as "turkey gnats," "buffalo gnats," "black flies," and "sand flies." They are related in a general way to the mosquitoes, crane flies, fungus gnats, and punkies, but may be readily distinguished from them by their general stoutness of body and broadness of wing. The legs of the mosquitoes and of most gnats are long and rather slender, but those of the sand flies are short and stout. Their general form is so characteristic that they are easily recognized. They possess very broad wings. Their bodies are short and the thorax so much arched that they appear, as Johannsen expresses it "humpbacked." (See Fig. 1, Plate XLIII.)

Technically the adults of this family are distinguished by the following characteristics:

Antennæ are but little longer than the head, flattened or cylindrical, 10-jointed; the two basal joints differentiated, the others closely united and never plumose.

The eyes are round or reniform and holoptic in the male; ocelli absent.

Proboscis is not elongated, possessing small horny labella and four-jointed palps. The first joint of the palp is short, the two following of equal length, and the last one longer and more slender than the preceding.

The thorax is arched, without a suture, and the scutellum small.

The abdomen is cylindrical, made up of 7 or 8 (or more) segments, and the genitalia are concealed.

The legs are strong and not elongate, the femora broad and flat, tibia usually with terminal spurs; first joint of tarsi longer than the following and usually dilated in the male, the last joint small; wings large and broad, with distinct alulæ, anterior veins thickened, the others slender, auxiliary vein terminating in the costa about the middle of the wing which is not continuous beyond the tip of the wing. (See Fig. 1, Plate XLIII.) Second longitudinal vein wanting, the first and third lying close to each other, the third arising from the first rectangularly before the end of the auxiliary vein; anterior cross vein very short, fourth vein curved, forked nearly opposite the anterior cross vein, the forks terminating near the tip of the wing. (See Fig. 1, Plate XLIII.)

Similium vittatum—Zetterstedt.*

(*Tribulatum* Lugger, *Decorum* (Walk), *argus* (Will).

ADULT—FEMALE. Gray, nearly bare; dorsum of thorax with five black stripes, the median one entire, the intermediate pairs interrupted, the exterior pair spotlike. Each segment of the abdomen with a black dorsal stripe, and basally on each side with a black spot, the penultimate segment black.

Wings whitish hyaline; halteres white; legs fuscous black; the front side of the anterior tibiæ, the base of the middle and hind tibiæ, and the base of the middle and hind metatarsi white; length 3 mm. (Zetterstedt.)

* Johannsen.

Coquillett adds the following: "FEMALE. Abdomen gray, bases of segments 3 to 7 or 8 marked with a velvet-black fascia produced backward in the middle and at the ends, length 2 to 4 mm. Found in New York, Minnesota, Kansas, Illinois, and California."

MALE. Hind tarsi bicolorous, mesonotum gray on sides and hind margin, center largely velvet-black without gray streak extending inward from humerus, sides of abdominal segments 4 to 7 with silvery white hairs. (Coquillett.) To this Johannsen adds: "The markings of the female of this species seem somewhat variable, the thoracic markings are usually quite distinct, the median stripe is nearly of uniform width excepting at the posterior end where it becomes narrower; the intermediate stripes are ʃ shaped, the extremities larger, the intermediate portion usually a hair line, sometimes obsolete, the exterior pair usually elongated spots. The abdominal markings are as described by Coquillett, though occasionally there are additional disconnected, velvet-black lateral spots, one on each side on segments 3, 4 and 7, and a pair on 5 and 6. Sometimes, also, owing either to the contracted condition of the abdomen or to the fasciæ being narrow, only the black projections of the fasciæ are visible on the more posterior segments, giving the appearance of three spots on each. The legs are often gray, the femoræ and tibiæ paler at the base, the tibiæ black at tip, the tarsi deep black except basal portion of middle and hind metatarsi, fore tibiæ with one spur, middle and hind with one pair. Tarsal claws of female simple.

LARVÆ. Caudal blood gills, 3 simple papillæ; the middle tooth of the labium simple and pointed, labium with six pairs of setæ on its ventral surface; somewhat mottled gray, the sides of each segment blackish; the head is of the usual reddish-brown color, the pale yellow antennæ long and cylindrical, the second joint about one-third of the length of the first; the third is a pointed process at the tip of the second. The fans have about 40 rays, the cilia being relatively minute; the mandibles are provided with three large apical teeth besides the row of secondary ones; the apical pair of bristles is present; the maxillary palpus has a few spines, and a tuft of a few spines on the basal joint; hypopharynx and labrum apparently like those of other species; the labrum has an elongate middle tooth, those at the end nearly as long, the intermediate ones short and there are six bristles in each of the

two longitudinal rows on the ventral surface; the three blood gills at caudal end, unbranched.

PUPA. The thoracic respiratory filaments each consist of a single main trunk, from which arise eight branches, each of which divides into two, thus making 16 twigs in all. Near the basal margin of the last few abdominal segments are a few caudal-projecting dorsal hooks, and on the tip of the last segment is a pair of blunt spines. The pupal case is of the wall-pocket type, from which the respiratory filaments of the pupa project.

GENERAL HABITS AND LIFE HISTORY OF THE FAMILY.

The habits of the adults are quite generally known because in many places they are fully as troublesome as mosquitoes. They are so-called "bloodsuckers," feeding upon the blood of horses, cattle, and man, sometimes to such an extent as to be of considerable economic importance. (See Riley in N. Y. State Mus. Bull. No. 68.) They lay their eggs on the surface of rocks over which shallow water is flowing rapidly, as on the rocks of shallow rapids and the ledges of waterfalls. Their eggs are laid in masses one layer deep. In about eight or ten days they hatch into larvæ which attach themselves by their caudal end to the rocks or stems of aquatic plants.

The larvæ retain their position in the swiftest current by means of a disc-like sucker on the posterior end of the body. When they desire to move to a new location they may do so by anchoring a silken thread to the support and, releasing their hold, spinning out their silk as they are washed downstream, but retaining control of it very much after the fashion of spiders suspending themselves in mid-air, or they may travel over the surface of the rocks with a looping gait similar to that of a measuring worm.

They are said to feed upon algæ, diatoms, and parts of phaneragamous plants.* In those I have examined diatoms have comprised most of the material found in the digestive cannal.

When the larva is ready to transform it spins a tough pupal case firmly attached to the rock and changes to a strangely shaped pupa. Then in due time the fly comes from the pupal skin, rises to the surface of the water and shortly takes flight.

* Miss R. Phillips, 1890, of Cornell University, reports that among the algæ taken by the larvæ are Nothix, Cladophora, and Vauchera. Walter T. Emery adds Conferva, Scenedesmus, Chlamydomonas, Euglena.

Mr. Emery in his paper on the "Morphology and Biology of *Simulium vittatum*" gives some interesting data regarding the biology of this insect, to which the reader is referred.

TECHNIQUE FOR THE STUDY OF GROSS ANATOMY.

Most of the studies of the gross anatomy of the *Simulium* fly were made by means of free dissections under the binocular.* Quite a number of the body tissues of the fly are transparent, and for a study of these the direct sunlight gave the best illumination. A spot light made by focusing sunlight through a reading glass gave excellent illumination. These studies were verified by serial microtome sections.

The comparatively small size of the fly (3 mm.) necessitated the use of a technique somewhat more delicate than is usually necessary, and inasmuch as the majority of students of small forms have failed to record their methods of study, I have felt it desirable to give a brief account of the technique used in these studies.

The needles used in the dissection work were made by placing the base of minuten nadeln points (used in mounting small insects) in handles of wood and grinding the points on emery paper until they were small enough for use.

The flies were held in any given position by paraffin. To do this, some paraffin was placed in a small shallow porcelain staining dish, and warmed to melting point. The fly was then placed about half its width in the paraffin in the desired position and the paraffin cooled.

The dish was then filled with either normal salt solution or with 50 per cent alcohol, depending upon whether the material was fresh or fixed. With careful work and a steady hand one could determine the various systems with considerable accuracy. One fly would usually serve for several days' dissection study, and by covering the dish with a lid and inverting a tumbler over all to prevent evaporation of the alcohol the specimen would be ready for further study without the usual delay.

Most of the dissections were made with the fly on its side. The large muscles of the thorax and the deep incision of the exoskeleton between the thorax and the abdomen made dorsal dissections quite unsatisfactory. Ventral dissections were

* I used a Zeiss machine and found that the No. 2 and No. 4 eye pieces used with the A2 objective gave by far the most satisfactory results for the study of general anatomy.

used only to verify the other studies by giving a different point of view.

SECTIONAL STUDY.

Killing and Fixing. In order to determine the best method of fixing and staining the adult flies it was necessary to try a number of fixations and stains.

The flies were divided into lots and killed and fixed in the following ways:

Six lots were treated with picro-aceto-sublimate for 12, 18, and 24 hours respectively. When they had been in the fluid the specified length of time, the liquid was carefully drawn off with a pipette, and the vials filled with 70 per cent grain alcohol. At the end of 24 hours the alcohol was changed by the pipette method as above, and this process of changing the alcohol repeated for 3 days. At the end of that time the 70 per cent was replaced with 85 per cent alcohol and the lots stored.

Six lots were captured and placed in picro-formal for 12 hours, 18 hours, and until they sank, respectively. They were then washed out with 70 per cent alcohol as for the picro-aceto-sublimate and stored in 85 per cent alcohol.

Two lots were fixed in Fleming's stronger mixture. The flies were allowed to remain in the fixing fluid until they sank. Then they were changed to water and washed for three days. From the water they were transferred to 95 per cent alcohol.

Six lots of live sand flies were fixed in Gilson's chloro-aceto-sublimate for 10 minutes, 20 minutes, and until they sank. They were then washed in 70 per cent alcohol for several days and stored in 85 per cent alcohol.

Six lots were fixed in Zenker's fluid for 6 hours, 12 hours, and until they sank, respectively. They were then washed out in water and transferred to alcohol containing tincture of iodine.

In the above series the chloro-aceto-sublimate gave the best fixation.

C. G. Hewett, '07, in his work with the house fly used Henning's solution made up as follows: Nitric acid 16 parts, chromic acid (.5 per cent) 16 parts, picric acid saturated in water 12 parts, and absolute alcohol 42 parts. After fixing the material he washed out in iodine water. This method he finds not only fixes but to a certain extent softens the chitin,

which facilitates sectioning, providing the material is not allowed to be imbedded too long.

Hot alcohol and hot Gilson's both give very good results for larval forms, as has been noted by Headlee, '06, in his work on *Simulium* blood gills.

Specimens killed in hot Perenyi's fluid, cut and removed to fresh fluid for six hours and then transferred to 70 per cent alcohol, were well fixed.

But the best fixation that I have tried was obtained by the use of Kable's Fixation. This was recommended to me by Dr. Brues, of Harvard, who used it as a fixation for the *Stomoxys calcitrans*. It is made up as follows: 30 parts water, 15 parts normal 95 per cent alcohol, 6 parts formaline (40 per cent), 1 part of glacial acetic acid. The flies are killed in this hot solution and transferred when cold to 70 per cent alcohol.

Since the Gilson's mixture mentioned above gave very satisfactory results it might also be well to give directions for making it. To make up a two-liter bottleful use:

30 cc. of 80 per cent nitric acid.
8 cc. of glacial acetic acid.
40 grs. corrosive sublimate.
200 cc. of 60 per cent alcohol.
1760 cc. of distilled water.

Infiltrating and Imbedding. When the specimens were desired for study, they were graded up from the 85 per cent alcohol to absolute alcohol in small glass dishes covered with ground glass covers. If they were stored in 85 per cent alcohol they were slipped up to 95 per cent and left for 48 hours to harden. Then from this they were transferred to absolute and left for a like time. From this they were transferred to a vial which had been half filled with xylol and then filled with absolute alcohol. Here they were left for 24 hours, after which they were returned to a glass dish of pure xylol. The dish was then placed on the top shelf of an electric drying oven, and a few flakes of paraffin dropped into it. When dissolved more were added and the dish placed nearer the heat. Bits of paraffin were added from time to time for the following six hours. By the end of that time the flies could be transferred to pure melted paraffin and left there for 24 hours or longer.

Cutting and Mounting. When the flies were infiltrated they were imbedded and cut in serial sections of from 4 to 15 microns in thickness.

The dry paraffin ribbons were placed on an absolutely clean slide and floated with prepared egg albumen. The albumen was then drained off and the slide held just enough below the surface of tepid distilled water to float out the folds and allow the ribbons to be arranged. The slides were then air-dried for one week, after which they were warmed enough to melt down the paraffin and placed in xylol for ten minutes. From the xylol they were passed down through the alcohols to the grade used in the stain.

Staining. Five stains were used in the studies made with the *Simulium* fly.

I. For thin sections to be studied for parasitic forms *Gemsa's Lasung* was used. This stain was diluted 1 drop to 1 cc. of water made faintly alkaline with weak potassium carbonate (1%). The sections were stained with this for fifteen minutes. (With this stain chromatin is stained blue and protozoa and bacteria pinkish.) Differentiation was made with tap water. After dehydrating in the alcohols they were transferred to xylol and from the xylol to the balsam mount.

II. For ordinary work the sections of any thickness were run down to 50% alcohol and stained for twelve hours in borax carmine, differentiated in acid alcohol, dehydrated and mounted as above.

III. Iron hæmatoxylin was used in the usual way.

IV. Good results were obtained by overstaining with Delafield's hæmatoxylin and differentiating with acid alcohol as suggested by Hewett.

V. The best results were obtained by running the sections down to 25% alcohol and staining in ferric alum for 4 hours, then Hædenhain's hæmatoxylin (5% aq. solution) for 12 hours. Following this they were bleached in ferric alum, placed in orange g. and dipped back and forth in the two stains till proper results were obtained as determined by following the action of the stains under the low-power compound. Then they were rehydrated, passed up through xylol, and mounted.

THE THORAX OF SIMULIUM.

The thorax of dipterous insects always presents a problem. The fact that they possess but one pair of wings has led to the adjusting of the thoracic box to meet these conditions. Thus the mesothoracic division which bears the wings is greatly developed while the prothoracic and metathoracic divisions are reduced. Time has not permitted a detailed report on the homologies of the several sclerites making up the prothorax. Suffice it to say that the prothoracic cylinder is not typical, the sclerites conforming not at all to our conception of the normal arrangement of parts. The mesothorax, on the other hand, is a simpler matter. The notum is large, occupying the whole of the dorsal side of the thorax. It is not transversed by well-marked sutures that could mark the præscutum, scutum, scutellum, and postscutellum. As a whole it is a convex shield. It is this sclerite that gives to *Simulium* its characteristic "humpedback" shape.

Laterally, we have the alar membrane for the wing attachment above and the episternum and epimeron below. The mesosternum is large and well marked. The metathorax bears the haltere and the metathoracic spiracle on its pleural aspects.

WINGS. The two wings are borne at the sides of the scutum of the mesothorax. They are attached, by means of the sclerites at the base of the wings, to the alar membrane. They are broad and characterized by having only the veins of the anterior portion of the wing developed, the other veins showing only as thickened but transparent tracings. (See Fig. 1, Pl. XLIII.) Following the nomenclature of Johannsen for this family I describe the venation of the wing as follows: The anterior edge of the wing is reënforced by the costa which extends to a point some little distance before the tip of the wing. The *subcosta* joins the *costa* at a point about one-third the distance from the base of the wing to the tip. *Radius* is all but fused with *subcosta*, showing up a clear line along the posterior edge of *subcosta* for $\frac{3}{5}$ of its length, (subcosta), it then appears as a separate vein. *R.* joins costa a little beyond the point where *subcosta* meets *costa*. This point is marked by a slight emargination in the costal margin of the wing. *R2-3-4-5* extends for a considerable distance, finally meeting *costa* shortly before its termination (costa). The base of *media* is well marked. This well-marked portion ex-

tends for the first 1/6 of the length of the vein. There a cross vein connects *media* with radius and the vein becomes transparent, soon branching into M_1 and M_2, M_1 extending to the tip of the wing and M_2 running out along the posterior side of the wing. *Cubitus* is represented more as a fold than as a vein. There are two clearly marked anal veins, *anal 1* being straight, and *anal 2* curved; the anal area lying posteriorly to the anal veins is creased by two folds.

LEGS. The legs of *Simulium* are stouter than those of most of the related forms. The following segments are present: *Coxa,* a strong cylindrical segment; *trochanter* narrow and somewhat irregular; *femur,* rather stout; *tibia,* about the length of *femur,* also stout; *tarsi,* 5-jointed, joint one about as long as the remaining joints taken together, the last bearing simple claws.

ALIMENTARY CANAL.

The alimentary canal is a comparatively straight tube extending from the buccal cavity to the anal opening in the last segment. (Fig. 2, Pl. XLIII.)

The Proboscis. This is made up by the close application of the hypopharynx to the so-called labrum and ensheathed by the fleshy labium. This strongly chitinized tube (Ph., Fig. 12, Pl. XLV) is well provided with muscular attachments as shown by the projection drawing of a section of the head (Fig. 12, Pl. XLV). At its upper end it meets the œsophagus, which passes back between commissures connecting the brain and subœsophagial ganglion.

It is joined near its base with the duct of the salivary glands by an apparatus shown in Fig. 11, and called by Meinert the "receptaculum" or salivary receptacle (Fig. 11, Pl. XLV).

The Œsophagus. The œsophagus joins the pharynx at right angles, this union being banded by a strongly chitinized collar (Fig. 11, C). It is smaller than the pharyngeal box, and is flanked by chitinized plates from which arise muscles that correspond to Meinert's musculature of Tabanus and have a similar function.

There arises from the dorsal wall of the œsophagus, caudad of the chitinized portion, a muscle that extends upward and backward to take its insertion in the wall of the vertex of the head. The œsophagus narrows as it passes from the head to

the thorax, being at this point little larger than the nerve cord just below it. Upon reaching the thorax it may change its direction slightly and continue its way through the thorax to the abdomen, or it may make a sudden bend dorsally and as abruptly bend back again, then continuing its course from there on as in the other case. In any event the slender portion of the tube suddenly enlarges, forming a tube of three times its diameter, the union of these two parts being marked by an enlargement, or a series of three enlargements. From the ventral side of this enlargement there arises a thin-walled duct (Fig. 11, Pl. XLV) that leads backward beneath the canal and expands into a rather large pouch. This duct can not strictly be defined as such, for it is simply the cephalic end of a sac which gradually narrows till it joins the digestive canal at the point shown in the figure (Fig. 11). The walls of this pouch are extremely thin and transparent when distended and at such times it occupies a considerable space in the abdomen. As shown in fig. 11 Fr. and in fig. 2 Fr. the pouch is somewhat contracted and shows muscle fibres. This sac by virtue of its position and union with the proventriculus leads to the conclusion that it must function as a food reservoir.*

The Stomach. The digestive tract upon passing into the abdomen usually turns dorsally for a short distance, where it enlarges to form an oval-shaped organ, the ventriculus or stomach. No cœcal tubes† have been found, but the surface of this mid-intestine is somewhat irregular, and it may be that the glandular areas in the wall of this organ will prove to function as cœcal glands.‡

Malpighian Tubes. Immediately below the mid-gut there arise on either side two tubes. These four tubes are of considerable length, and lie folded and doubled back on themselves above the mid-intestine and above and around the hind gut. These are the Malpighian tubules. Their natural position in the body is shown in fig. 2 pl. XLIII. Each tubule extends forward to cephalic end of stomach where, after making a loose double loop, it turns back to end with a half turn around rectal pouch. They are best studied in the male and freshly emerged female or in specimens treated for some time in 15

* Gordon Hewitt refers to a similar organ in the house fly as the crop.

† They are recorded as present in the larva of *Simulium* by Miall and Hammond.

‡ Haseman, 1910, considers a group of cells in the region of œsophageal valve of Psychola alternata as a reduced cœcal gland.

per cent chloral hydrate. Vaney, '02, finds that these tubes pass from the larva to the adult without any transformation, so that an examination of the larva gives a fair idea of their position in the adult. Just caudad of the region where the Malpighian tubules are attached, the hind gut takes a turn dorsally to a point below the junction of the fifth and sixth segments, and then bends caudad at right angles to about the seventh segment where the tube becomes first constricted and then dilated, especially on the lower side, which gives the appearance shown in r. p. fig. 2, pl. XLIII. This rectal enlargement is a transparent sac, the wall of which is distinctly striated (see Fig. 3, Pl. XLIII) and contains suspended from its upper or cephalic end six cone-shaped papillæ or glands, the rectal glands (see Fig. 3, RP). Each of these is made up of glandular cells containing large nuclei. An examination of the rectal pouch after treating it for some little time with caustic potash shows not only the estodermal origin of the papillæ but the presence of tracheal filaments as well.

Rectal papillæ have been observed in a number of insects. Chironomus has two, the house fly four, the stable fly four, most Hymenoptera, Neuroptera and Orthoptera six, Lepidoptera 60-200, and Coleoptera and Hemiptera none.*

Salivary Glands. The salivary glands are a pair of organs which lie in the fore part of the thorax on either side of but dorsally to the œsophagus. (Fig. 4.) They are connected with the common duct beneath the œsophagus by means of slender ducts. (See Fig. 4, Pl. XLIV.) They lie so close to the prothoracic wall and so near to the large tracheal trunks of the mesothoracic spiracle that they are often difficult to demonstrate. They lie on either side, between the second oblique and first longitudinal layer of muscle. Structurally they are in two parts. There is an upper part, which when stained shows itself to be glandular (see Fig. 4, Pl. XLIV) and a nonglandular part or sac. The glandular part is shown in sections to consist of thick-walled pouches, the cells of which contain large nuclei. In structure they resemble somewhat the acinous glands figured by Packard (after List). They do not at all resemble the trilobed glands of the mosquito or the slender glands of Stomoxys. They appear to be somewhat similar to those figured by Newstead for Phlebotmus.

* Miall and Hammond.

The Heart. This is shown in fig. 2 h., pl. XLIII. It lies along the dorsal wall of the abdomen till near the thorax, where it dips ventrally to a position just above the alimentary canal and extends forward, passing through a cellular mass above the region of the œsophagial valve and on into the head.*

The Fat Body. The fat body often occupies a considerable portion of the abdomen and is made up of many lobes. Figure 9 shows the fat bodies of a female fly after being fixed in alcohol for a time (ventral view).

The Nervous System. The nervous system is less specialized than in many other Diptera. The three thoracic ganglia are large while the five ganglia of the abdomen are comparatively small, the last two being close together and the terminal one larger than the others. (For general position and relative size see Fig. 6, Pl. XLIV.)

THE RESPIRATORY SYSTEM.

The respiratory system (Fig. 5, Pl. XLIV) consists of two longitudinal trunks running from the head to the posterior end of the abdomen. These are connected in the thorax by a large commissure, and in the head by a small one. The head and thorax are well supplied with large tracheal branches while the abdomen possesses a great network of tiny thread-like tubes arising from the rather small tracheal trunks. These little tubes ramify to all parts of the abdomen, binding together the loosely joined ova of the female, interlacing the many loops and folds of the Malpighian tubes and tying the fat body with all to the digestive canal. Thus we find in the abdomen on either side a longitudinal tracheal trunk, and throughout a mat of slender tracheal filaments. These tracheal trunks are not straight tubes, but curved at the six points where the branches leading to the abdominal spiracles are given off, namely, at the points between the second and third, third and fourth, fourth and fifth, in the fifth and in the sixth segments; the spiracular openings being located on the lateral surface of the body as follows: first one in the second segment near the junction of second and third, second one in third near the junction of second and third, third one in middle of segment 4, fourth one near the middle of segment 5, fifth one near the middle of segment 6, sixth one in seventh segment near its union with segment 6. These spiracles show up

* Gordon Hewett states that the dorsal vessel of the horse fly terminates in a mass of cells on dorsal side of ventriculus.

indistinctly as dark dots on the gray surface of the insect but show plainly in specimen treated with caustic potash. They are not functional in the larva and pupa, their work being taken over by the blood gills in the larva and by the cuticular gills in the pupa.

Taylor, '02, finds that the general scheme of tracheation is, however, about the same in the larva and pupa stages as in the adult, save for method by which the air is brought into the system mentioned above. His studies were upon *Simulium latipes*, and in his researches he records but five abdominal spiracle branches, failing to find the one in the second segment, which he thinks, however, must exist in view of the fact that the cast pupal skin shows an attached remnant of such a branch. He also infers that one exists in the first in some vestigial form, but I am unable to confirm this.

In the thorax there is a tendency of the tracheal branches to be dilated, and the fact that there are several large trunks or branches originating at the metathoracic spiracle and extending forward in different planes of the thorax makes it difficult to distinguish the main trunk from the others. In fact, if my interpretation is not incorrect, the main trunk is much smaller than the very large branches that are sent off. (See Fig. 5, Pl. XLIV.) This main trunk extends from the metathoracic spiracle underneath the large oblique thoracic muscles and runs along dorsolaterally to the fore gut, turning up before the first oblique muscle to meet the other branches extending from the mesothoracic spiracle. It then continues to the head where it breaks into many branches. These main trunks are connected in the thorax by one prominent commissure arising from the caudal end of the anterior third and looping up over the alimentary canal to the top of the second longitudinal muscles and thence back in the same plane between the right and left longitudinal thoracic muscles, joining the corresponding trunk on the other side. From the metathoracic spiracle there arise the following branches: one extending dorso-cephalad laterally to the main muscles of the thorax for some distance, then narrowing suddenly, it turns in under or between the outer oblique muscles, four and five, and gives off one small branch; another has the same general direction but lies in the plane between second oblique and first longitudinal and extends to the thoracic wall, where it turns ventro-cephalad at right angles and drops beneath the sixth

longitudinal muscle; another in this same plane extends ventrally, supplying the legs; while another leads forward to join the system again at the mesothoracic spiracle.

At the mesothoracic spiracle we find a number of branches, the direction of which may be best observed by referring to the drawings.

The mesothoracic spiracle lies well toward the front of the thoracic box and might well be mistaken for prothoracic in origin, but Taylor gives the following reason for considering it mesothoracic: Immediately in front of the anterior thoracic spiracle of the fly a well-marked apodeme or thickening of the cuticle runs obliquely backward to the mid-ventral line, where it unites with a similar thickening on the other side. The fore leg of the fly is inserted on the body in front of this apodeme, and muscles from the leg are attached to it. As the apodeme approaches the mid-ventral line, it bears the ante-furca, which, wherever it occurs, marks the junction of the pro and meso thorax. The anterior spiracle of the thorax lies close behind the apodeme which carries the antifurca, and is therefore mesothoracic in position.

Sexual Organs of the Female. The female *Simulium*, like most other related forms, possesses two ovaries, which lie on either side of the alimentary canal. (See Figs. 6 and 9.) These may occupy only the caudal third of the abdomen in case of the freshly emerged female, or take up all the available space in the abdominal cavity, even crowding into the thorax around the fore gut in case of females ready to oviposit.

When the newly emerged female is examined, the ovary appears as a transparent pouch showing practically no differentiation. But when this is removed and stained with borax carmine the ova are deeply stained and are seen to lie in regular order within the ovarian sheath. As the ova mature they lose their regularity of order and uniformity of shape, so that by the time they mature they are but loosely joined together and extremely irregular in outline. The latter is brought about by their crowded condition in the body of the insect. The eggs at maturity are relatively large, and when we are able to count as many as 276 ova packed in the body of a single female we do not wonder that they are so angular in form.

The oviduct connecting the ovarian sac with the exterior is comparatively easy to trace in the early adult stage. Here the oviducts are seen to join, forming a short tube, "the vagina," which passes to the genicular opening on the ventral side of the body between the penultimate and antipenultimate segments. (Fig. 8.) Dorsocaudad of the vagina lies a small chitinized spherical pouch, the spermathecæ. (Fig. 7.) This spermatheca is .09 mm. in diameter and dark-brown in color, with a thick chitinous covering. It is attached to the distal end of the common oviduct by a white cylindrical tube. The attachment of this white tube to this hard brown sphere reminds one of a germinating seed. It is interesting to note that with this fly there is but one functional spermatheca. In all the related species of flies that have been studied there are two—Phlebotomus, *Musca domestica, S. calcitrans,* Culex and the chironomids have two. When the genital apparatus is dissected and stained with borax carmine the two accessory pouches shown in figure 7 are found to be glandular in nature.

In concluding this brief sketch of the anatomy of the sand fly it may be well to state:

1st. That the three blood-sucking species studied for comparison of internal structures conform quite closely to the one here reported.

2d. That the digestive tract has three enlargements: the fore part of the proventriculus, the stomach, and the rectal pouch which contains six glandular rectal papillæ.

3d. That it is joined in the pharynx by the common duct of a pair of salivary glands which are located cephalo-dorsad to the proventriculus and well forward in the shoulder of the thorax, and at the junction of mid and hind gut, by four Malpighian tubules.

4th. That the reproductive organs are similar to those of related insects, save that but one spermatheca is found and this lies to the left side.

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PLATE I.

FIG. 1.—*Head of Cricket.*

This drawing shows the *epicranial suture* (*E. SU.*) which divides the paired sclerites from the single ones.

F.—The *front*, the first of these single sclerites, between the arms of the inverted Y of the suture, bears here the median ocellus and also the paired ocelli.

C.—The *clypeus.* The suture between the front and the clypeus is distinct. The clypeus is partly divided by a transverse suture; the part next the front is designated as *first clypeus* (*c1*), and that next the labrum as *second clypeus* (*c2*).

L.—The *labrum* is the last of the three single sclerites between the arms of the epicranial suture and the mouth. It is a single movable flap, constituting the upper lip of the mouth, having the appearance of an appendage, but in reality is a single sclerite, a portion of one of the head segments.

Tr.—*The trochantin of the mandible* is a small sclerite at the base of the *mandible* (*M*).

FIG. 2.—*Head of Cockroach.*

E. SU.—The *epicranial suture* is here present.

F.—The *front* bears the paired ocelli, but the median ocellus is absent.

C.—The *clypeus.* There is no suture between the front and the clypeus, but the *tentorium invaginations* (*at*) are quite distinct, and the dotted line connecting these points indicates the position of this obsolete suture. There is no distinct transverse suture dividing the clypeus, but the shading (indicated by second dotted line) gives the appearance of two parts.

L.—The *labrum* is present.

Tr.—The *trochantin* of the mandible is present.

FIG. 3.—*Head of the Larva of Corydalis.*

E. SU.—The *epicranial suture* here is very low down toward the mouth.

F.—The *front* is greatly reduced in comparison with the two forms already studied. The median and paired ocelli are wanting.

C.—The *clypeus.* Suture between front and clypeus is absent. Clypeus divided into three sclerites in transverse row, one on median line called *clypeus proper,* lateral sclerites called *antecoxal pieces of mandibles* (*ac*). Clypeus proper is divided by definite transverse suture into first and second clypeus (*c1* and *c2*).

Trochantin of mandible not visible.

At.—Tentorium invaginations present.

L.—*Labrum* present.

O. O.—The *occiput* as a definite area, formed of the upper portion of the postgenæ, is here shown back of vertex (*v*).

PLATE I—*continued.*

FIG. 4.—*Head of Walking-stick.*

E. SU.—*Epicranial suture* present but not so distinct.

F.—The *front* bears the ocelli.

C.—The *clypeus.* The suture between the front and the clypeus is obsolete, but the invaginations of the *tentorium,* though faint, are sufficient to mark the line of division. Transverse suture of the clypeus visible.

Ac.—*Antecoxal pieces* of the mandibles small.

Tr.—*Trochantin* of the mandible small but present.

L.—*Labrum* present.

FIG. 5.—*Head of Mantis.*

E. SU.—*Epicranial suture* small and indistinct.

F.—The *front* bears the median and paired ocelli. Transverse ridge of front so prominent that it appears at first sight to be division between front and clypeus.

C.—The *clypeus.* Presence of *tentorium* invaginations show that there is a strongly marked suture between the clypeus and front, instead of the upper ridge being the division. Clypeus undivided by sutures.

Ac.—*Antecoxal pieces* of mandibles small, merely indicated.

Tr.—*Trochantin* of mandibles present but very small.

FIG. 6.—*Head of Dahinia.*

E. SU.—*Epicranial suture* very indistinct; arms of Y form nearly straight line. Front might easily be considered part of epicranium.

F.—*Front.* Ocelli absent.

At.—*Tentorium* invaginations discernible. Suture between front and clypeus strongly marked.

C.—*Clypeus* divided by transverse suture.

Ac.—Position of *antecoxal pieces* apparent.

L.—*Labrum* apparently consisting of two parts, much like labrum of grasshopper.

Tr.—*Trochantin* of mandible present.

FIG. 7.—*Head of Orchelimum.*

E. SU.—*Epicranial suture* present only as fastigium of vertex (*v*).

F.—*Front* increased by pushing up of *E. SU.*; bears median ocellus.

C.—*Clypeus.* No suture between front and clypeus, but invaginations of tentorium very distinct. No transverse suture dividing clypeus, so that front and clypeus appear as one sclerite.

At.—*Tentorium* invaginations distinct.

Ac.—*Antecoxal* pieces not really discernable; position simply inferred on frontal margin of clypeus.

Tr.—*Trochantin* of mandible present.

L.—*Labrum* large.

PLATE I—*concluded.*

FIG. 8.—*Head of Decticinæ.*

E. SU.—Epicranial suture as in *Orchelimum.*

F.—Front containing trace of median ocellus.

C.—Clypeus. All divisions of clypeus indicated. Suture between front and clypeus present.

At.—Tentorium invaginations present.

L.—Labrum present.

Tr.—Trochantin of mandible present.

FIG. 9.—*Head of Grasshopper.*

E. SU.—Epicranial suture pushed up to point of vertex (*v*).

F.—Front large; bears ocelli.

C.—Clypeus. Suture between front and clypeus present. Divided by transverse suture into first and second clypeus.

Ac.—Antecoxal pieces indicated.

At.—Tentorium invaginations present.

L.—Labrum appears to be divided into two parts by transverse suture.

Tr.—Trochantin of mandible small but present as a distinct sclerite.

FIG. 10.—*Head and Neck of Cockroach.*

This drawing shows the lateral view of the epicranium, which includes all of the paired sclerites of the skull and sometimes also the front. The paired sclerites constitute the sides of the head and that portion of the dorsal surface that is behind the arms of the *E. SU.* These sclerites are so closely united that Straus-Durckheim considered them a single piece.

V.—Vertex, the portion of the epicranium which is next the front and between the compound eyes. In some insects it bears the paired ocelli, but not in the Plecoptera.

G.—Genæ, lateral portions of the epicranium.

Pg.—Postgenæ. The genæ are divided by a well-marked suture, which in the specimens at hand ended definitely. The part back of this suture is known as the postgena. When this suture continues to the epicranial suture the upper parts form the *occiput.*

Tr.—Trochantin of the mandible.

Md.—Mandible.

Mx.—Maxilla.

Mem.—Maxillary epimeron. A very small, narrow sclerite just back of the postgenæ.

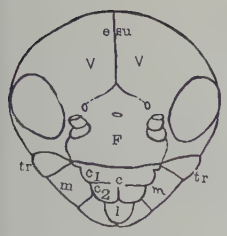
This drawing also shows one dorsal, two lateral, and one ventral cervical sclerite.

FIG. 11.—*Head of Adult Corydalis, Ventral Aspect.*

This drawing shows a *gula,* a sclerite forming the ventral wall of the hind part of the head in certain orders of insects and bearing the labium or second maxillæ.

In the more generalized orders this sclerite or the one corresponding to it does not form a part of the skull.

PLATE I.



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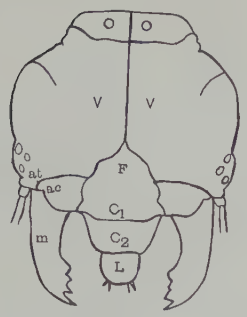

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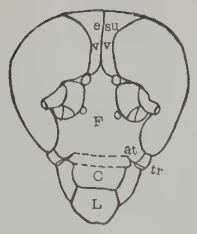

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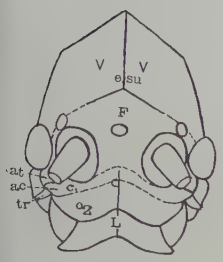

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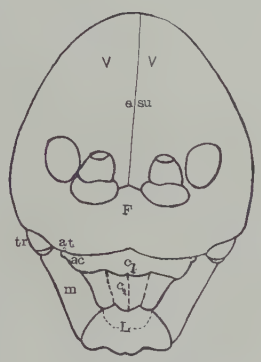

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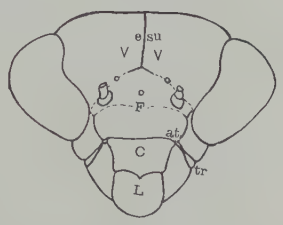

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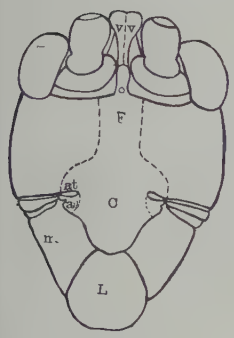

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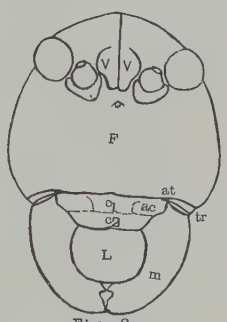

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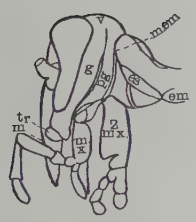

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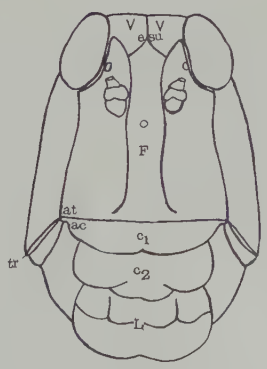


Fig. 9.

Fig. 11.

PLATE II.

FIG. 12.—*Embryo of a Damsel Fly* (*Calopteryx*).

(After Brandt.)

The question of the number of segments in the head of an insect has been much discussed. Savigny (1816) first made the suggestion, which has been accepted by all, that the movable appendages of the head were homodynamous with legs.

By methods of comparative anatomy, therefore, it has been found that there are at least four segments in the head: *i. e.*, the *antennal*, the *mandibular*, the *maxillary*, and the *second maxillary* or *labial*. The presence of a fifth segment (the ocular) has been suggested, as the compound eyes are borne on movable stalks in certain Crustacea, which might therefore place them among the movable appendages of the head.

The embryologists have taken up the question and Brandt (fig. 12) has shown in the embryo of the damsel fly that there are distinct segments, each corresponding to a pair of mouth-parts: *a*, antennal; *md*, mandibular; *mx*, maxillary; *2mx*, second maxillary.

The labial and maxillary segments appear to be body segments rather than cephalic. It is thought that perhaps "this represents a phylogenetic stage in which the head proper consisted of fewer segments than it does in existing insects."

FIG. 13.—*Embryo of Hydrophilus.*

(After Heider.)

Heider found that the subœsophageal ganglion which innervates the mandibles, maxillæ and labium is formed by the union of at least three pairs of primitive ganglia. His figure represents a stage in the development of *Hydrophilus*, in which these ganglia are still distinct, each pair of ganglia corresponding to a pair of mouth parts.

FIG. 14.—*Head of Embryo of Anurida.*

(After Folsom.)

FIG. 15.—*Section of the Head of an Embryo of Anurida.*

(After Folsom.)

The embryologists having confirmed the conclusions of comparative anatomy, have further demonstrated the existence of vestiges of segments. They have discovered a pair of ganglia between those of the mandibular and maxillary segments. (Fig. 14, *sl*; and fig. 15, *5*.)

FIG. 16.—*Head of Embryo of Acilius.*

(After Patten.)

As long ago as 1888 Patten figured the subœsophageal ganglion as consisting of four pairs of primary ganglia.

Some thought that the second of these four pairs of primary ganglia referred to the mandibular ganglia, because they are immediately in front of the maxillary; but according to the results of Folsom (figs. 14

and 15) and Uzel, the lingua arises between the maxillæ, and the superlingua between the maxillæ and the mandibles. Therefore, it is more probable that the first of these four pairs of ganglia (fig. 16, *1-4*) belongs to the mandibular segment and that the second pair are the homologues of the superlingual ganglia.

FIG. 17.—*Diagrams of the Elements of the Head.*

(After Comstock and Kochi.)

A.—Lateral aspect.

B.—Ventral aspect.

To illustrate the morphological relations of the arrangement of segments of the head, they are represented as distinct, of uniform size, and in a direct line:

First. Outline of segments made.

Second. Longitudinal line representing line of separation of sternal and pleural elements of segments.

Third. Chain of ganglia added, 1 pair for each segment.

Fourth. Compound eyes and the ocelli were represented in the first segment because innervated by the protocerebrum.

Fifth. Position of the appendages indicated, a pair to each segment except first. Antennæ to second segment because innervated by deutocerebrum.

Sixth. Mouth represented as opening in ventral wall of third segment.

FIG. 18.—*Ventral Aspect of the Metathorax of a Nymph of Pteronarcys.*

(After Comstock and Kochi.)

FIG. 19.—*Ventral Aspect of the Metathorax of Stenopelmatus.*

(After Comstock and Kochi.)

The position of the furca within the body is represented by a dotted line.

A typical segment is composed of: a ventral part, sternite; two lateral parts, pleurites; and a dorsal part, tergite.

Each thoracic segment is composed of two subsegments. The line separating these subsegments passes, on the pleural aspect, between the episternum and the epimeron; and on the tergal aspect, between the scutum and scutellum. The division on the sternal aspect is not so easily recognized, but it is clearly evident in the nymphs of *Pteronarcys* and *Stenopelmatus.* (Figs. 18 and 19, *s* and *s2.*)

The invaginations forming the furca lie in the suture between the two sclerites, and are therefore a landmark for determining the division between them.

FIG. 20.—*Ventral Aspect of the Meso- and Meta-thorax of Gryllus.*

The position of the furcæ within the body are indicated by dotted lines.

PLATE II—*concluded.*

FIG. 21.—*Diagram of a Segment of an Embryo.*

(After Heymons.)

Figure 20 shows that the sternellum is often obsolete, so that the furcæ appear to arise from the caudal margin of the segment.

Figure 21.—Heymons has shown that in a comparatively early embryonic stage each segment of the body is composed of three parts: a median field (*mf*), and two lateral fields (*lf*), and that the appendages are developed as evaginations of the lateral fields (*lg*).

Figure 20.—The abdominal sternites of the adult gryllus show the lateral elements of the sternites, the portion lying between the appendage and the median field (*lf*).

As a rule each sternite is an undivided sclerite.

FIG. 22.—*Ental Surface of the Pleurites of the Meso- and Meta-thorax of Melanoplus, Showing the Lateral Apodemes.*

The lateral apodemes show the line of union of the subsegments on the pleural aspect of a thoracic segment.

FIG. 23.—*The Base of a Leg of a Cockroach.*

This shows the relations of the appendages to a typical segment:

x, Point of pleural articulation of the coxa, ventral end of the foot of the lateral apodeme of the segment, the ventral end of the episternum (*es*), and epimeron (*em*).

y, Ventral articulation of the coxa; *sp*, spiracle; *ap*, apodeme; *ac*, antecoxal piece; *2ac*, second antecoxal piece; *tr*, trochantin; *es*, episternum; *em*, epimeron.

PLATE II.

Fig. 12.

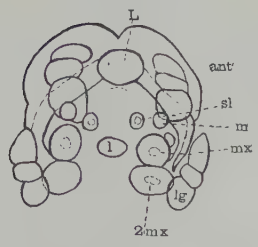
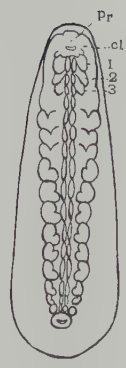


Fig. 14.



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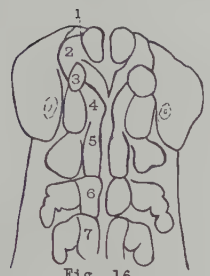


Fig. 16.

Fig. 15.

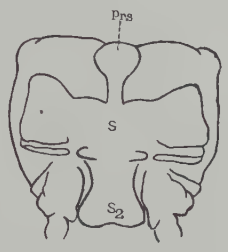


Fig. 18.

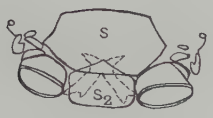
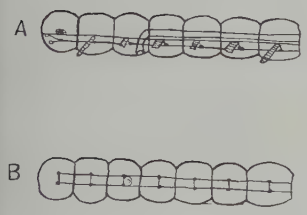


Fig. 19.



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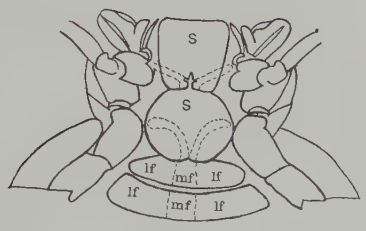

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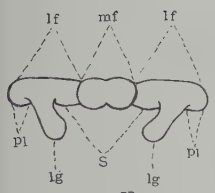

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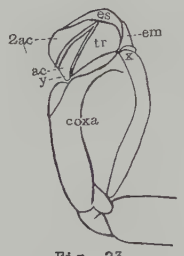


Fig. 23.

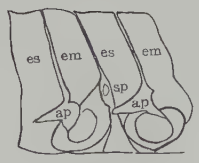


Fig. 22.

PLATE III.

FIG. 24.—*Head of a Cricket, Ental Surface of the Dorsal Wall.*

This shows: *os*, the ocular sclerites, which may be the basal segment of the ocular appendage; *as*, the antennal sclerite, which represents the lateral field of the antennal segment.

FIG. 25.—*Head of the Nymph of Pteronarcys.*

(After Comstock and Kochi.)

In this the antennal sclerites (*as*) are distinct and closer to the clypeus than in the more specialized insects, showing that it is possible that they were once closely connected with the clypeus (*c*) and a part of the same segment.

FIG. 26.—*Lateral Cervical Sclerites of Melanoplus.*

These are taken to represent the epimeron (*em*) and episternum (*es*) of the labial segment.

There is present a prominent apodeme (*ap*), and the epimeron connects with the episternum of the prothorax, and the episternum (*es*) with what is considered the epimeron of the maxillary segment.

FIG. 27.—*Head of Stenopelmatus, Ventral Aspect.*

(After Comstock and Kochi.)

This shows the ventral cervical sclerites in two transverse series, *S* and *S2*. These may be regarded as the sternum and sternellum of the labial segment.

FIG. 28.—*Ventral and Lateral Cervical Sclerites of Periplanata.*

This shows the two single cervical sclerites—the sternum (*s*) and the sternellum (*s2*) of the labial segment; also the lateral cervical sclerites —the episternum (*es*) and the epimeron (*em*) of the labial segment.

FIG. 29.—*Ventral Cervical Sclerites of Gryllus.*

In *Gryllus*, as in *Stenopelmatus* the ventral cervical sclerites are arranged in two transverse series.

FIG. 30.—*Hypopharynx of Melanoplus.*

This shows the lingua (*l*) and the superlinguæ (*sl*), the sole remaining traces of the superlingual segment. These are small sclerites, probably representing the appendages of that segment.

This also shows the pharyngeal sclerites (*ps*), the sternal elements of the mandibular segment.

FIG. 31.—*Head of a Cricket, Caudal Aspect.*

Pg.—Postgenæ.
Es.—Episternum.
Em.—Epimeron.
M. ap.—Mandibular apodeme.
Bt.—Body of tentorium.
Ex. h.—Extensors of the head.
D. ap.—Dorsal apodeme.

This is to show the parts that are considered as belonging to the mandibular segment.

M. ap. is the acetabulum into which a condyle of the mandible fits, and which is the beginning of a suture which divides the *pg.* into two parts, the episternum and the epimeron. "The mandible is the basal segment (coxa) of an appendage, which articulates with the ventral ends of two sclerites (episternum and epimeron), between which there is a lateral apodeme."

FIG. 32.—*The Tentorium of a Cockroach, Dorsal Aspect.*

Pt.—Posterior arm of tentorium.
Bt.—Body of tentorium.
Fp.—Frontal plate of tentorium.
Dt.—Dorsal arm of tentorium.
T. oe.—Tendons of œsophageal muscles.
At.—Anterior arm of tentorium.
C.—Clypeus.
L.—Labrum.

FIG. 33.—*Head of Melanoplus, Caudal Aspect.*

V.—Vertex.
O.—Occiput.
Pg.—Postgenæ.
Pt.—Posterior arm of tentorium.
Bt.—Body of tentorium.
Mx.—Maxillæ.
2nd Mx.—Second maxillæ or labium.

FIG. 34.—*Tentorium of Melanoplus, Cephalic Aspect.*

The distal ends of the dorsal arms detached.
O.—Occiput.
Pg.—Postgenæ.
Pt.—Posterior arms of tentorium.
Bt.—Body of tentorium.
At.—Anterior arms of tentorium.
C.—Clypeus.
L.—Labrum.

PLATE III.

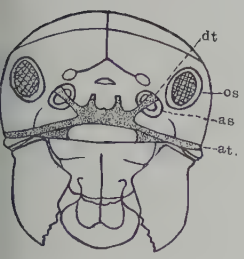


Fig. 24.

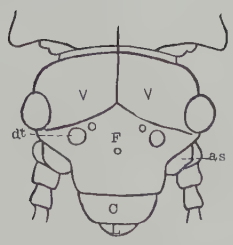


Fig. 25.

Fig. 27.

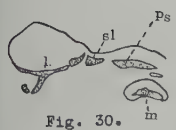
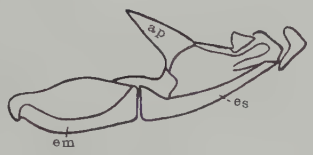


Fig. 30.

Fig. 28.



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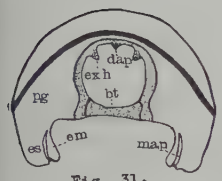
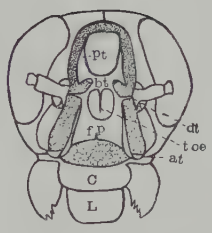


Fig. 31.

Fig. 29.



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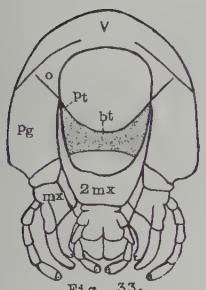

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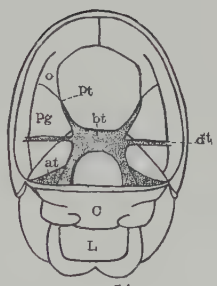


Fig. 34.

PLATE IV.

FIG. 35.—*Head of Amblychila cylindriformis.*

O.—Occiput.
V.—Vertex.
F.—Front.
C.—Clypeus.
L.—Labrum.
G.—Gena.
Tr.—Trochantin of the mandible.
Md.—Mandible.
At.—Anterior arm of tentorium.
Esu.—Epicranial suture.

FIG. 36.—*Head of Amblychila cylindriformis, Ventral Aspect.*

Pg.—Postgenæ.
Gu.—Gula.
Dt.—Dorsal arm of tentorium.
Em.—Epimeron.
a.—Small chitinized spots, which may be remnants of lateral cervical sclerites.

FIG. 37.—*Head of Amblychila cylindriformis.*

O.—Occiput.
Es.—Episternum.
Dt.—Dorsal arm of tentorium.
Em.—Epimeron.
Pg.—Postgena.
Gu.—Gula.
a.—Chitinized spot.

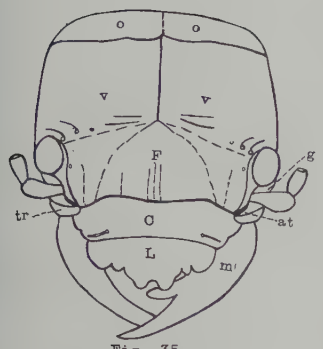
FIG. 38.—*Sclerites of Neck.*

Legend as above. *S2.*—Sternellum.

FIG. 39.—*Tentorium of Amblychila, Dorsal Aspect.*

Bt.—Body of tentorium.
Dt.—Dorsal arm of tentorium.
At.—Anterior arm of tentorium.
Os.—Ocular sclerite.

PLATE IV.



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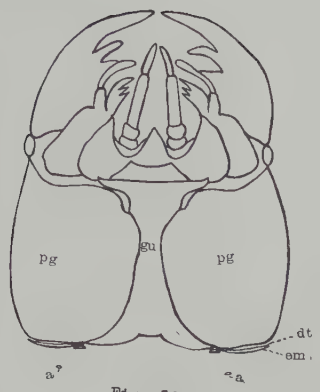

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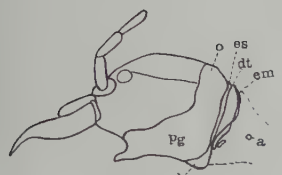


Fig. 37.

Fig. 38.

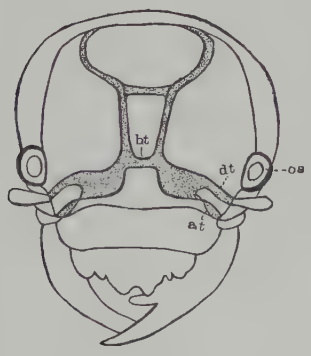


Fig. 39.

PLATE V.

FIG. 1.—Dorsal aspect of *Entylia sinuata*. Prothorax removed. *a*, head; *d*, compound eye. Mesathorax: *b*, præscutum; *c*, scutum; *f*, scutellum; *e*, post-scutellum. Metathorax: *g*, præscutum; *h*, scutum; *i*, scutellum; *k*, post-scutellum.

FIG. 2.—Metathoracic leg of *Entylia sinuata*. *a*, coxa; *b*, trochanter; *c*, femur; *d*, tibia; *e*, tarsi; *f*, claws.

PLATE V.

Fig.-I

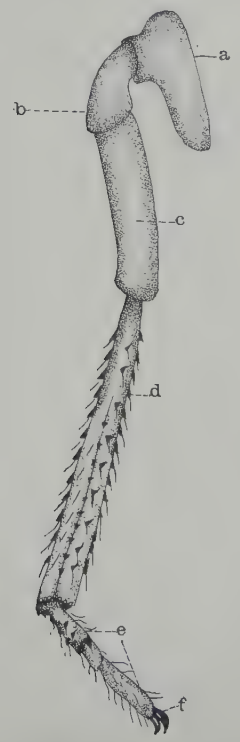


Fig.-2-

PLATE VI.

FIG. 5.—Dorsal aspect of *Ceresa bubalus*. *a*, metopidium; *b*, dorsum; *c*, posterior process; *d*, tegmina; *e*, suprahumeral.

FIG. 6.—Prothorax of *Ceresa diceros*.

FIG. 7.—Lateral aspect of *Ceresa bubalus*. *x*, humeral angle.

FIG. 8.—Prothorax of *Ceresa taurina*.

FIG. 9.—Front aspect of head of *Ceresa taurina*.

FIG. 10.—Front aspect of head of *Ceresa bubalus*. *a*, metopidium crest; *b*, front of metopidium; *c*, compound eye; *d*, ocelli; *e*, antennæ; *f*, clypeus.

PLATE VI.

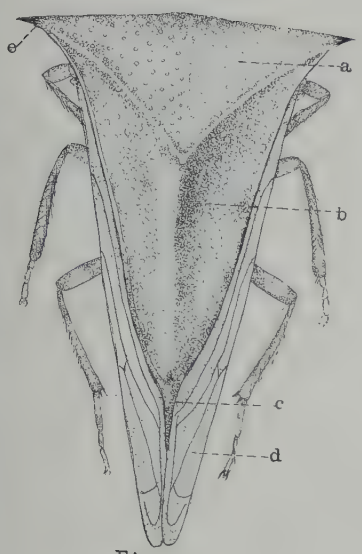


Fig. 5.

Fig. 6.

Fig. 7.

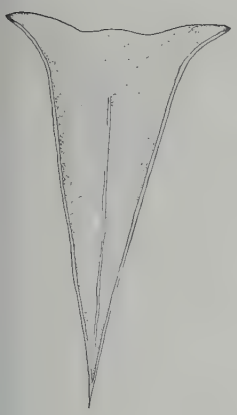
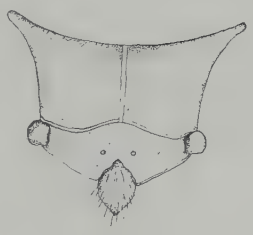


Fig. 8.



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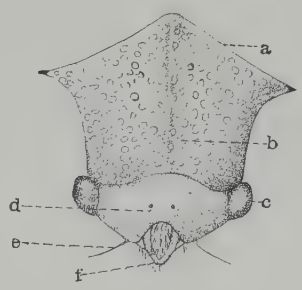


Fig. 10.

PLATE VII.

FIG. 11.—Lateral aspect of *Campylenchia curvata*. *a*, procephalon; *b*, metopidium.

FIG. 12.—Cephalic aspect of *Enchenopa binotata*. *c*, procephalon; *d*, metopidium; *e*, suprahumeral.

FIG. 13.—Lateral aspect of *Enchenopa binotata*.

FIG. 16.—Cephalic aspect of head of *Stictocephala inermis*. *g*, metopidium sloping backward; *f*, front of metopidium.

FIG. 17.—Lateral aspect of *Stictocephala inermis*.

PLATE VII.

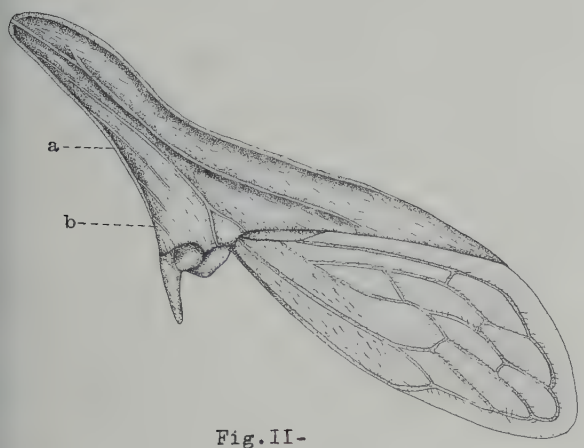


Fig.II-

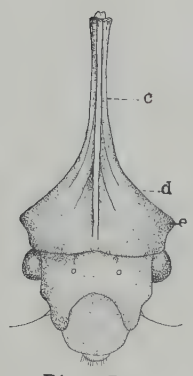


Fig.-I2-

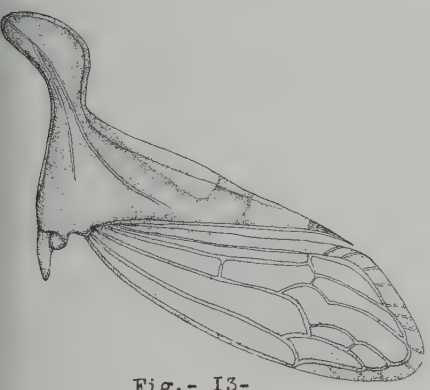


Fig.- I3-

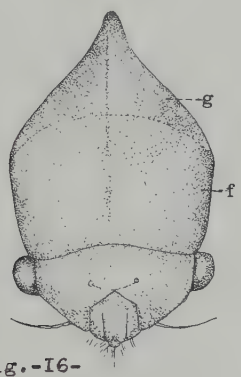


Fig.-I6-

Fig.-I7-

PLATE VIII.

FIG. 14.—Cephalic aspect of head of *Vanduzea arquata.*

FIG. 15.—Lateral aspect of *Vanduzea arquata.*

FIG. 18.—Cephalic aspect of head of *Acutalis tartarea.*

FIG. 19.—Lateral aspect of *Acutalis tartarea.*

FIG. 20.—Cephalic aspect of *Micrutalis calva.*

FIG. 21.—Lateral aspect of *Micrutalis calva.*

FIG. 30.—Cephalic aspect of *Telamona pyramidata.*

FIG. 31.—Lateral aspect of *Telamona pyramidata.*

PLATE VIII.

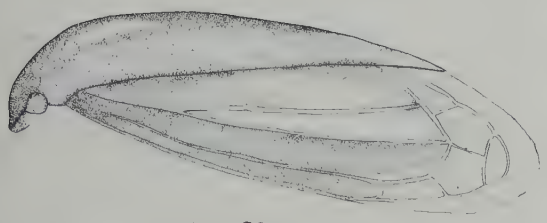


Fig.-I9-

Fig.-I4-

Fig. -20-

Fig. -I8-

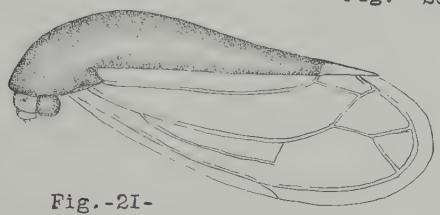


Fig.-2I-

Fig.-I5-

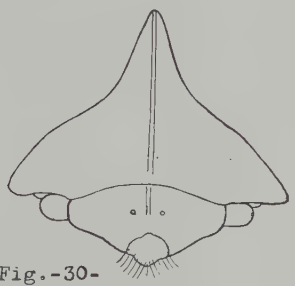


Fig.-30-

Fig.-3I-

PLATE IX.

FIG. 22.—Cephalic aspect of *Archasia galeata.*

FIG. 23.—Lateral aspect of *Archasia galeata.*

FIG. 24.—Cephalic aspect of *Cyrtolobus vau.*

FIG. 25.—Lateral aspect of *Cyrtolobus vau.*

FIG. 26.—Cephalic aspect of *Publilia concava.*

FIG. 27.—Lateral aspect of *Publilia concava.*

FIG. 28.—Cephalic aspect of *Stictocephala lutea.*

FIG. 29.—Lateral aspect of *Stictocephala lutea.*

PLATE IX.

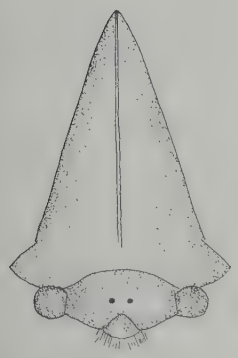
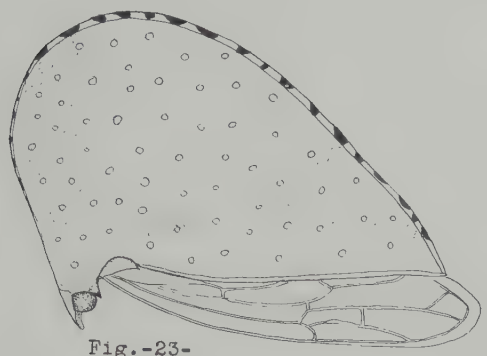


Fig.-22-



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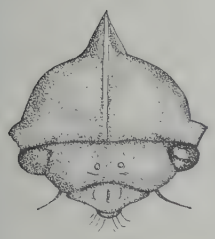


Fig.-24-

Fig.-27-

Fig.-26-

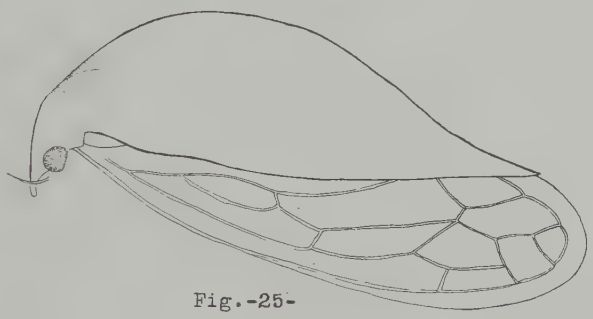


Fig.-25-

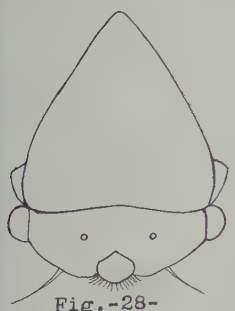


Fig.-28-

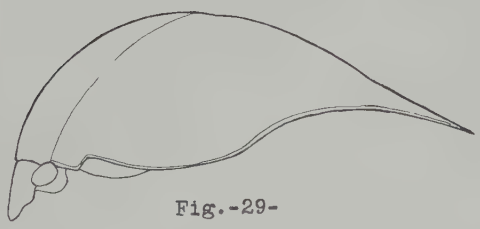


Fig.-29-

PLATE X.

FIG. 32.—Cephalic aspect of the head of *Publilia modesta.*

FIG. 33.—Lateral aspect of *Publilia modesta.*

FIG. 34.—Lateral aspect of prothoracic arm, showing position and connection to coxa of prothoracic leg. *b*, cavity for head; *c*, coxa of leg; *d*, under sclerite of prothoracic arm; *e*, prothoracic arm; *f*, indentation where compound eye fits.

FIG. 73.—Lateral aspect of *Telamona ampelopsides.*

FIG. 74.—Cephalic aspect of *Telamona ampelopsides.*

PLATE X.

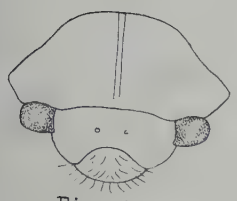


Fig.-32-

Fig.-33-

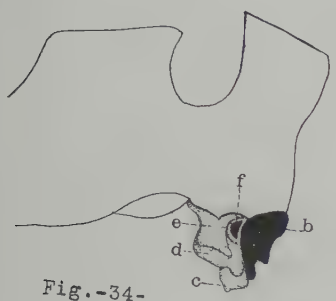


Fig.-34-

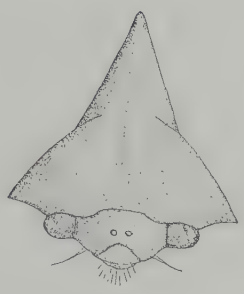


Fig. 74.

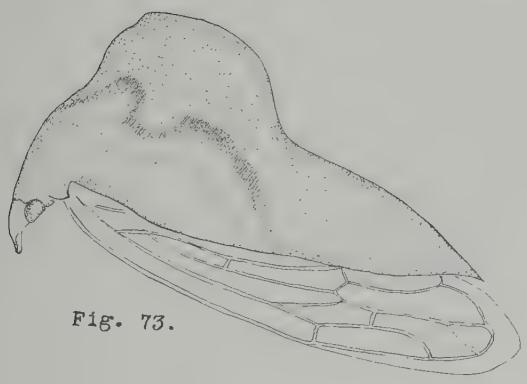


Fig. 73.

PLATE XI.

FIG. 35.—Cephalic aspect of head of *Entylia sinuata.* *e,* epicranium; *s,* epicranial suture; *o,* ocelli; *c,* compound eye; *l,* loræ; *y,* clypeus (cephalic face); *a,* antennæ.

FIG. 36.—Antennæ of *Entylia sinuata.* *s,* socket; *m,* basal segment; *n,* second segment bearing sensoria; *t,* third segment; *x,* hairlike termination of the third segment.

FIG. 37A.—Ventral aspect of head of *Entylia sinuata.* *x,* epicranium; *o,* ocelli; *c,* compound eye; *a,* antennæ; *g,* genæ; *f,* cephalic face of clypeus; *y,* ventral face of clypeus; *m,* mandibular sclerite; *n,* maxillary sclerite; *lb,* labrum; *p,* epipharynx; *l,* the three joints of the beak, called labium; *s,* maxillary setæ.

FIG. 37B.—*m,* tip of mandibular setæ; *n,* tip of maxillary setæ.

FIG. 38A.—Lateral aspect of head of *Entylia sinuata.* *c,* compound eye; *d,* cephalic face of clypeus; *y,* ventral face of clypeus; *l,* labrum; *e,* epipharynx; *g,* gena; *m,* mandibular sclerite; *x,* maxillary sclerite; *n,* floor of mouth; *k,* the three joints of the labium.

PLATE XI.

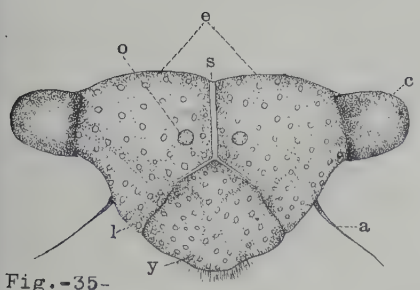


Fig.-35-

Fig.-36-

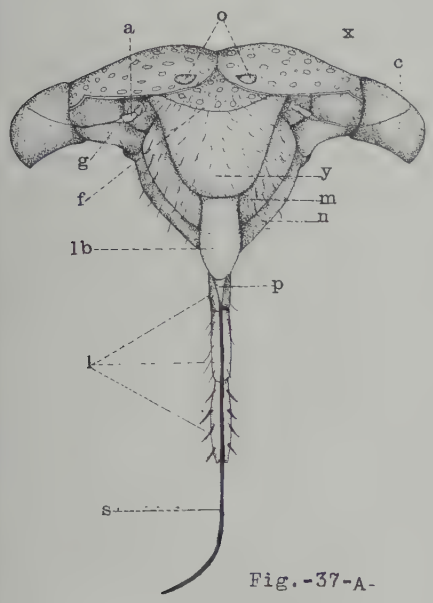


Fig.-37-A-

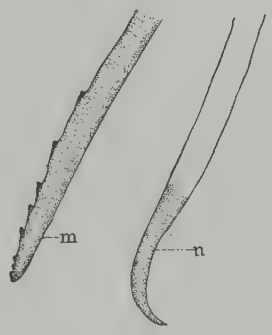


Fig.-37-B-

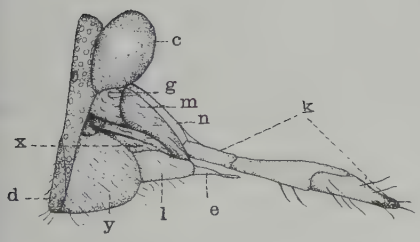


Fig.-38-A-

PLATE XII.

FIG. 38B.—Beak of *Entylia sinuata*. *b*, tip of labrum; *p*, epipharynx; *l*, labium; *n*, seta of maxillæ.

FIG. 39.—Interior of front of mouth. *y*, clypeus; *x*, mandibular sclerite; *n*, distal tip of mandibular sclerite; *h*, hypopharynx; *e*, grooved inner surface of epipharynx; *z*, tip of epipharynx, the portion beyond labrum; *l*, edge of labrum, curving inward to help hold setæ.

FIG. 40.—View of the head on the side resting against the body. *y*, cavity into head; *m*, muscle holding head to thorax; *e*, epicranial suture; *o*, occiput; *c*, compound eye; *t*, tentorium, with its branches which lead into the head and thorax; *r*, rod which supports the labium; *n*, floor of mouth; *x*, maxillary sclerites; *l*, three joints of the labium.

FIG. 41.—Back of head, with one maxillary sclerite removed to show the mandibular sclerite which lies in front of it. *o*, occiput; *x*, maxillary sclerite; *p*, maxillary process which guides the setæ; *s*, maxillary seta; *y*, muscle connecting the maxillary seta to the sclerite; *m*, mandibular sclerite; *b*, mandibular seta; *v*, shows the articulating joint which connects the seta to the sclerite; *n*, muscle which holds the mandibular seta to the cranium.

FIG. 42.—Cephalic aspect of the head, with the mandibular and maxillary sclerites pulled apart. *e*, epicranium; *c*, front face of the clypeus; *y*, ventral face of the clypeus; *d*, mandibular sclerite; *x*, maxillary sclerite. The cross indicates where the seta is joined to the sclerite.

PLATE XII.

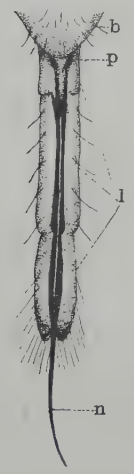


Fig.-38-B-

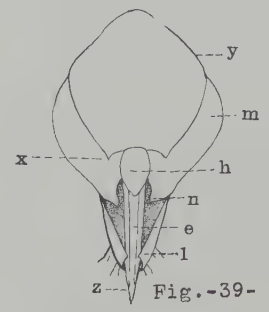
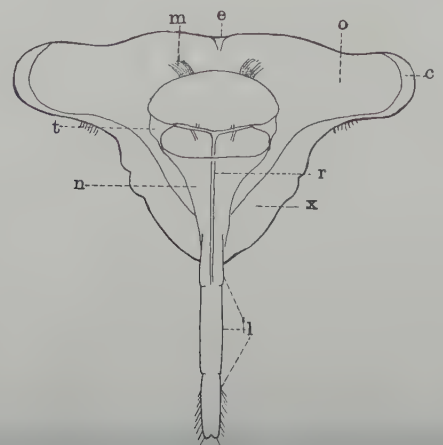


Fig.-39-



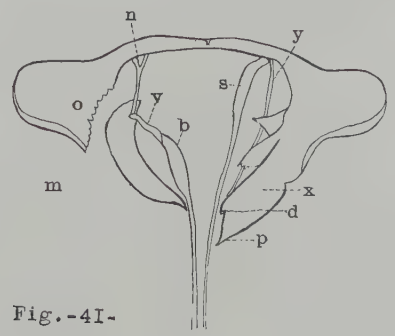


Fig.-4I-

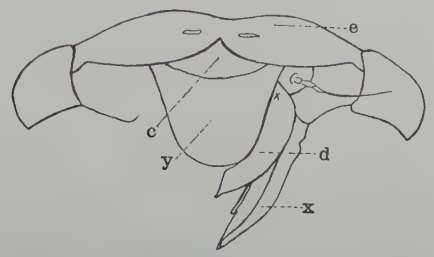


Fig.-42-

PLATE XIII.

FIG. 43.—Section through the first segment of the beak. *a*, support rod; *b*, inner edge of beak; *c*, outer edge of beak; *d*, edge of labrum; *e*, mandibular setæ, showing opening to form a tube; *f*, maxillary setæ, showing the manner in which the two are grooved together to form the tube.

FIG. 44.—Section through the second segment of the beak. *a*, indentation for support rod; *b*, outer edge of beak; *g*, inner edge of beak; *d*, epipharynx; *e*, mandibular setæ; *f*, maxillary setæ.

FIG. 45.—Section through the middle of the third or last segment of the beak. *a*, indentation for support rod; *b*, inner wall of beak; *c*, outer wall of beak; *f*, maxillary setæ; *e*, mandibular setæ; *m*, muscles.

FIG. 46.—Section through the tip of the beak. *a*, indentation for support rod; *c*, *b*, outer wall; *x*, maxillary setæ; *m*, muscles.

FIG. 47.—Cross section of the head, the plane being parallel with the cephalic face. *p*, ring of the pharynx; *x*, maxillary setæ; *d*, mandibular setæ; *y*, clypeus; *m*, muscles supporting the clypeus; *xs*, maxillary sclerite; *ds*, mandibular sclerite.

PLATE XIII.

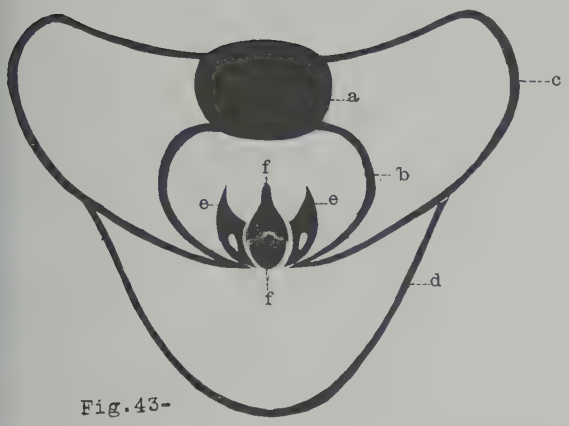


Fig.43-

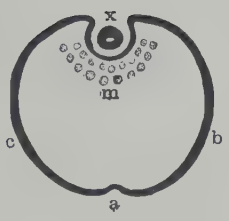


Fig.-46-

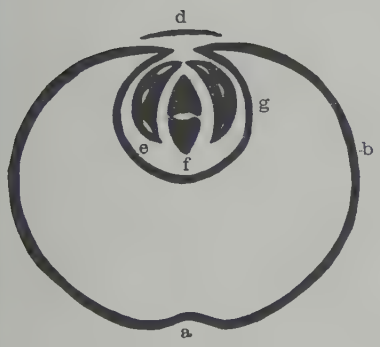


Fig.-44-

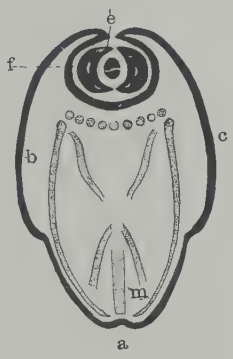


Fig.-45-

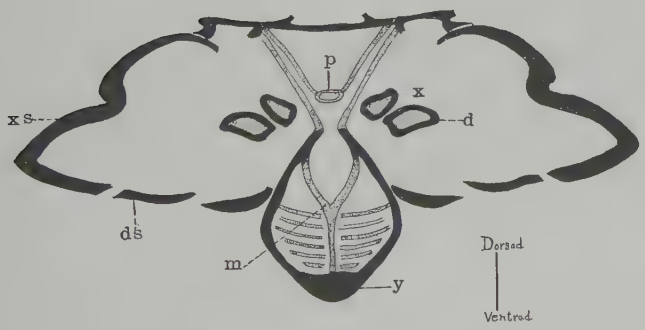


Fig.-47-

PLATE XIV.

FIG. 48.—Cross section parallel with the beak and maxillary sclerite. *e*, compound eye; *o*, optic nerve; *h*, ring of pharynx; *x*, maxillary seta; *a*, muscle holding the seta to the cranium; *r*, retractor; *p*, protractor muscles; *d*, mandibular seta; *t*, retractor; *n*, protractor; *c*, pumping muscles; *m*, muscles which operate the pharynx near the epipharynx.

FIG. 49.—Cross section near the back of the head parallel with the cephalic face. *b*, lower brain; *s*, upper brain; *h*, œsophagus; *m*, muscle which supports the œsophagus; *x*, maxillary seta; *o*, optic nerve.

FIG. 51.—Ventral aspect of the reproductory organs of the male. *a*, last abdominal segment; *s*, subgenital plate; *r*, claspers; *x*, *z*, claspers; *k*, copulatory organ; *y*, anal plates.

FIG. 52.—Lateral aspect of the tip of the abdomen of the male. *y*, supra-anal plate; *p*, cercus; *r*, claspers; *x*, *z*, claspers; *y*, anal plate, bearing the copulatory organ on its ventral side.

PLATE XIV.

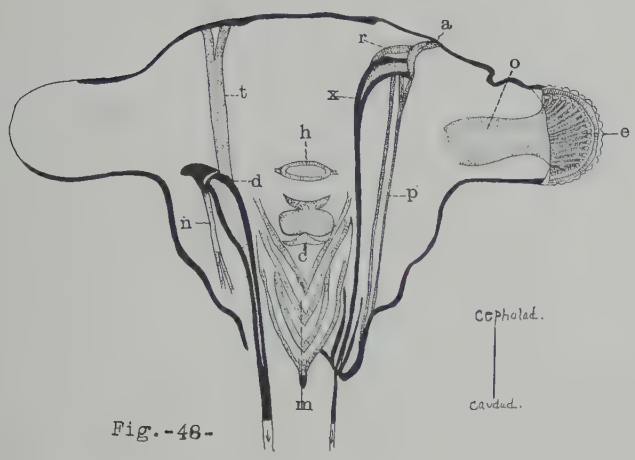


Fig.-48-

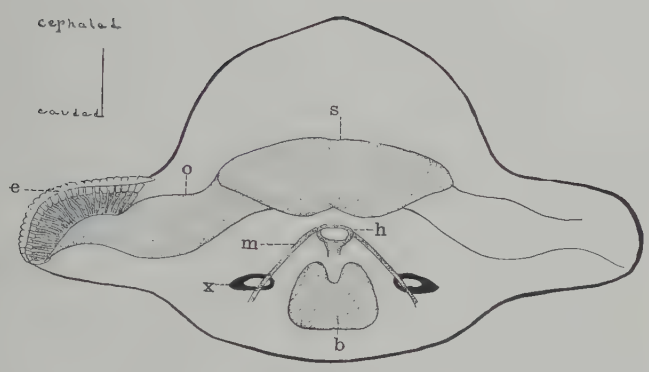


Fig.-49-

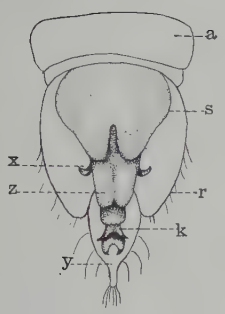


Fig.-5I-

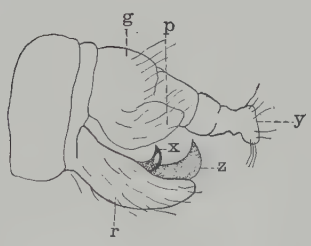


Fig.52-

PLATE XV.

FIG. 50.—Longitudinal section of the head. *a*, back of beak lying against the sternum; *b*, supraœsophagal ganglion, or upper brain; *e*, subœsophagal ganglion, or lower brain; *r*, support rod; *p*, pumping muscles, or salivary ejaculator; *k*, duct leading from salivary glands; *o*, duct from salivary ejaculator (*p*) to œsophagus; *f*, floor of mouth; *v*, muscles; *j*, muscles; *x*, maxillary seta; *g*, epipharynx; *l*, labrum; *n*, muscles governing pharynx; *u*, muscles governing pharynx; *z*, clypeus (ventral face); *y*, clypeus (cephalic face); *t*, *m*, muscles supporting clypeus; *h*, hypopharynx.

FIG. 53.—Ventral aspect of the tip of the female abdomen. *v*, ventral plate; *g*, supra-anal plate; *r*, egg guides; *e*, claspers; *o*, oviducts; *y*, anal plates.

FIG. 54.—Lateral aspect of the tip of the female adbomen. *g*, supra-anal plates; *y*, anal plates; *gs*, subgenital plates; *r*, claspers; *e*, egg guides; *v*, last ventral segment of the abdomen.

PLATE XV.

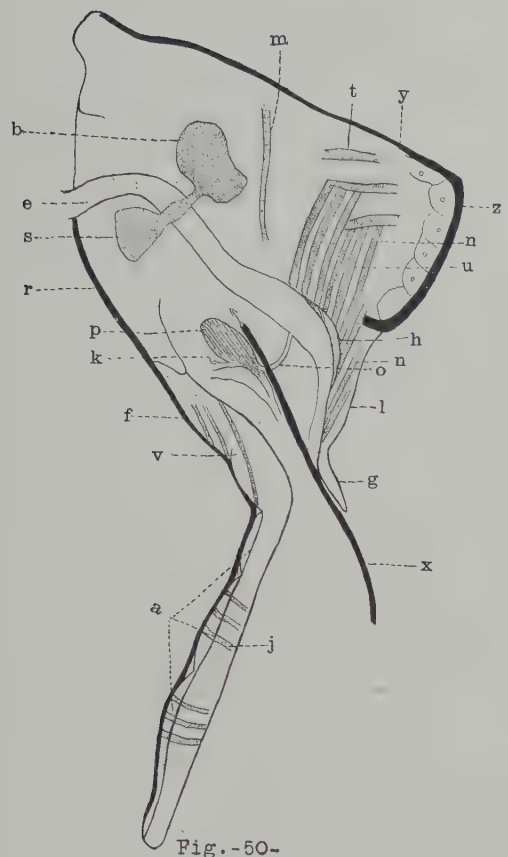


Fig.-50-

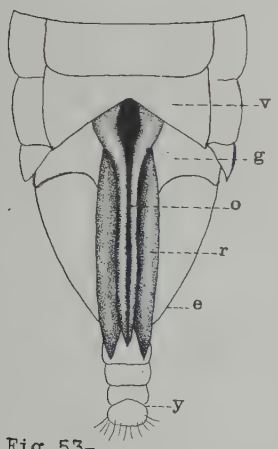


Fig.53-

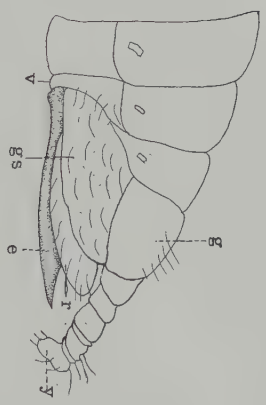


Fig.-54-

PLATE XVI.

FIG. 55.—Leaf of *Cnicus altissimus*, showing, at *A*, the egg mass laid by *Entylia sinuata*.

FIG. 56.—*B*, enlarged drawing of vein containing egg mass. The vein is burst open. *C*, an egg enlarged 31 times; *x*, micropyle.

FIG. 57.—Ventral aspect of newly hatched nymph of *Entylia sinuata*.

FIG. 58.—Dorsal aspect of nymph of *Entylia sinuata* after first moult.

FIG. 59.—Lateral aspect of nymph of *E. sinuata* after second moult.

FIG. 60.—Lateral aspect of nymph of *E. sinuata* after third moult and just preceding the adult stage. This is the pupa.

FIG. 61.—Lateral aspect of *E. sinuata*.

FIG. 62.—Cephalic aspect of the head of *E. sinuata*.

PLATE XVI.

Fig.-55-

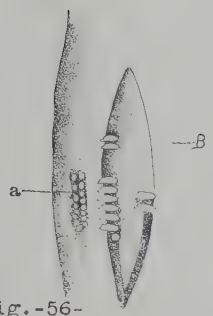


Fig.-56-

Fig. 57-

Fig.58-

Fig.-59-

Fig. 60-

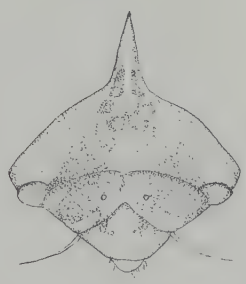


Fig. 62-

Fig.-6I-

PLATE XVII.

FIG. 63.—Tegmina and wing of *Micrutalis calva.*

FIG. 64.—Tegmina and wing of *Entylia sinuata.*

FIG. 65.—Tegmina and wing of *Publilia concava.*

FIG. 67.—Tegmina and wing of *Cyrtolobus vau.*

PLATE XVII.

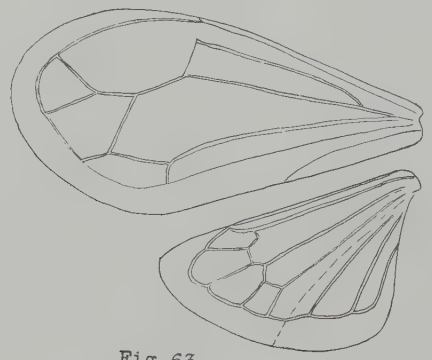


Fig.63-

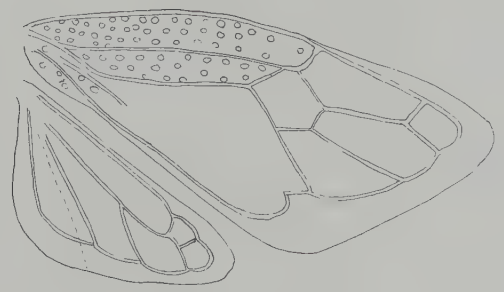
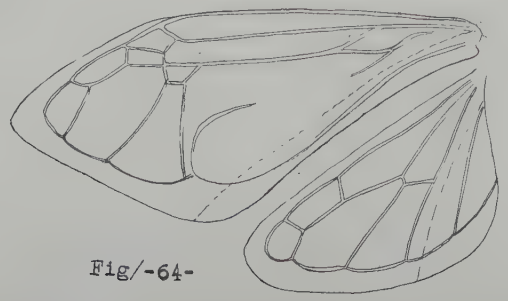


Fig.-65-



Fig/-64-

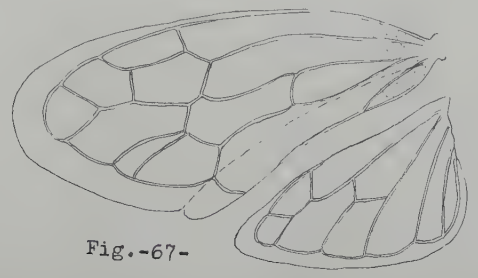


Fig.-67-

PLATE XVIII.

FIG. 66.—Tegmina and wing of *Stictocephala inermis.*

FIG. 68.—Tegmen of species determined in K. U. collection as *Vanduzea vestita.*

FIG. 69.—Tegmen and wing of *Vanduzea arquata.*

FIG. 70.—Tegmen and wing of *Campylenchia curvata.*

PLATE XVIII.

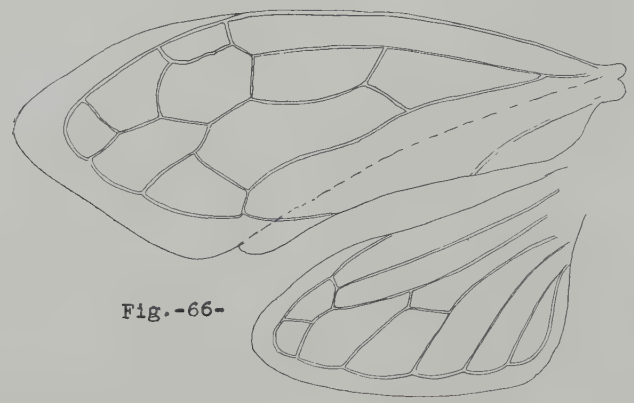


Fig.-66-

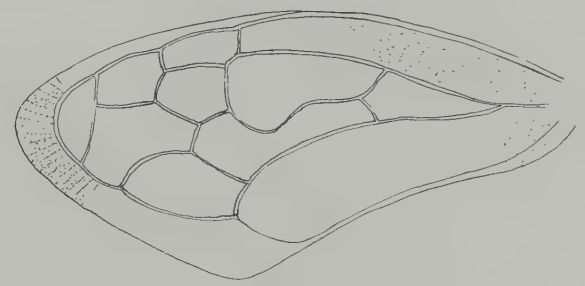


Fig.68-

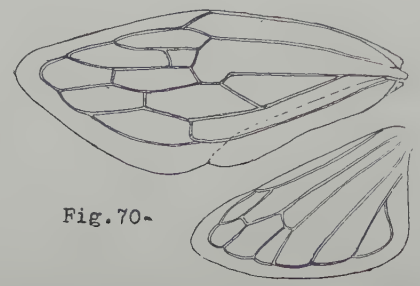


Fig.70-

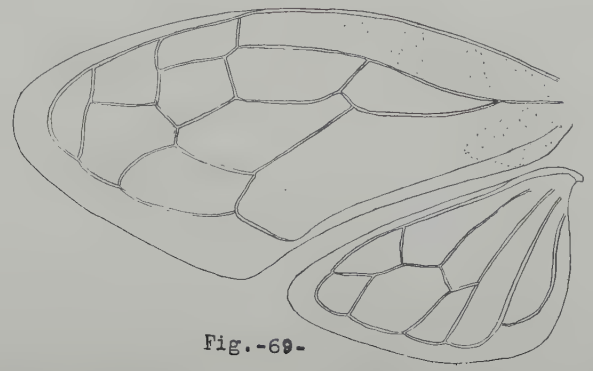


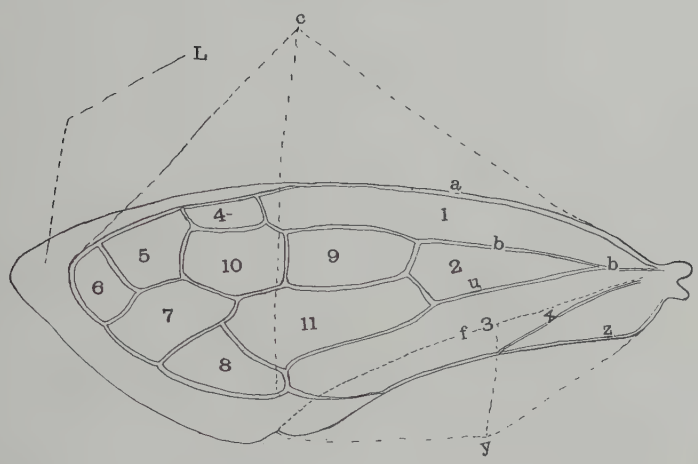
Fig.-69-

PLATE XIX.

FIG. 71.—Tegmen and wing of *Enchenopa binotata.*

FIG. 75.—Tegmen of *Ceresa bubalus* with veins and cells named. *L*, limbus or membrane; *c*, corium or embolium; *a*, costa; *b*, radia; *u*, ulnar; *x*, *z*, anals; *1*, *2*, *3*, basal cells; *3*, also sutural area; *f*, sutural fold; *9*, *10*, *11*, discoidal cells; *4*, *5*, *6*, *7*, *8*, apical cells; *6*, terminal apical cell; *y*, clavus.

PLATE XIX.



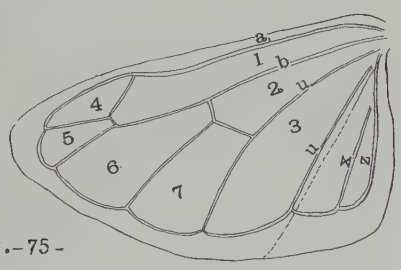


Fig.-75-

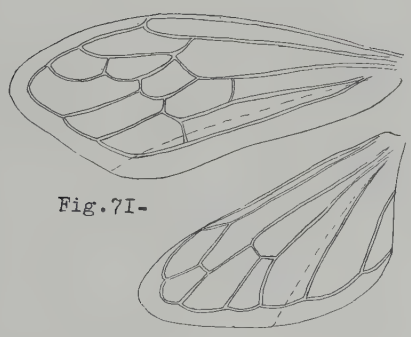


Fig.7I-

PLATE XX.

FIG. 76.—Legs of *E. sinuata.* *a,* prothoracic leg; *b,* mesothoracic leg; *c,* metathoracic leg.

FIG. 77.—Legs of *Campylenchia curvata.* *a,* prothoracic leg—the coxa and femur have separated; *b,* mesothoracic leg; *c,* metathoracic leg.

FIG. 78.—Tegmen of *Vanduzea arquata.*

FIG. 79.—Tegmen of *Cyrtolobus vau.*

FIG. 80.—Tegmen of *Acutalis tartarea.*

FIG. 81.—Tegmen of *Micrutalis occidentalis.*

FIG. 82.—Tegmen of *Micrutalis calva.*

FIG. 83.—Tegmen of *Entylia sinuata.*

FIG. 84.—Tegmen of *Telamona pyramidata.*

PLATE XX.

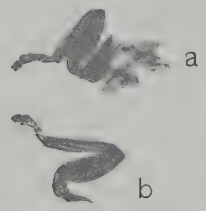


Fig.-78-

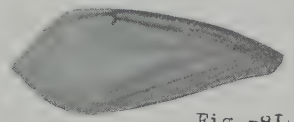


Fig.-8I-

Fig.-82-

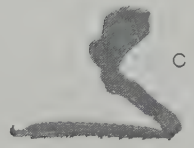


Fig.-76-

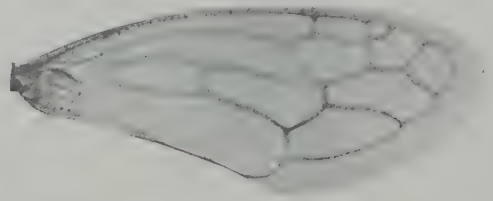


Fig.-79-

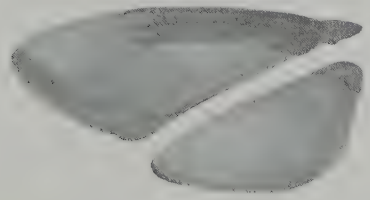
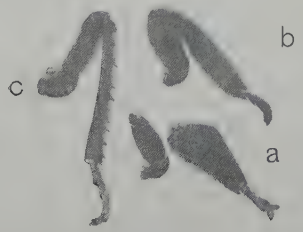


Fig.-83-



Fig/-77-

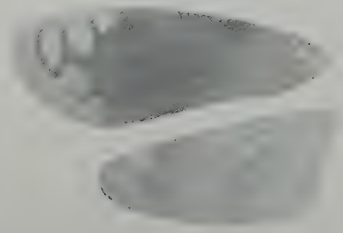


Fig.-80-

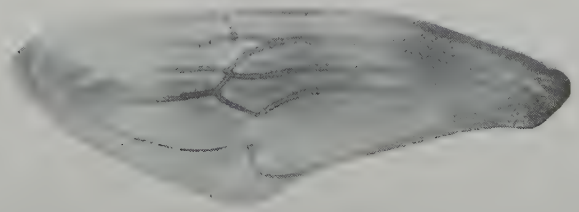


Fig.-84-

PLATE XXI.

FIG. 3.—Cercopidæ.
FIG. 4.—Cicadidæ.
FIG. 85.—Tegmen of *Enchenopa binotata.*
FIG. 86.—Tegmen of *Campylenchia curvata.*
FIG. 87.—Tegmen of *Ceresa bubalus.*
FIG. 88.—Tegmen of *Ceresa diceros.*
FIG. 89.—Tegmen of *Stictocephala inermis.*
FIG. 90.—Tegmen of *Stictocephala lutea.*

PLATE XXI.

Fig.-86-

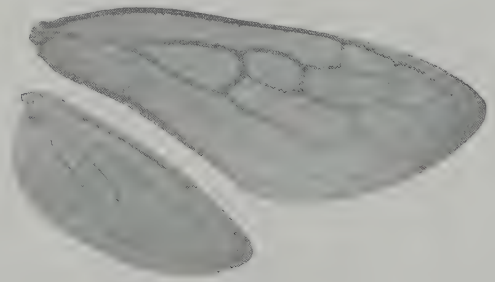


Fig.-88-

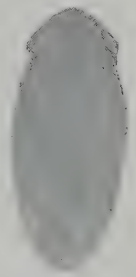


Fig. 3.

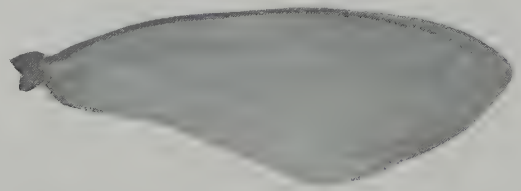


Fig.-87-

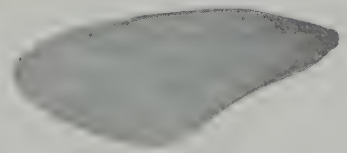


Fig.90-

Fig. 4.

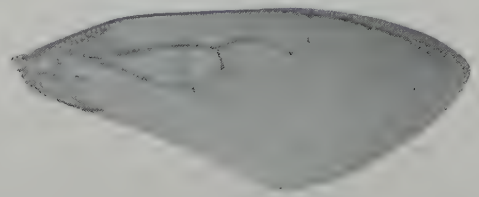


Fig.-89

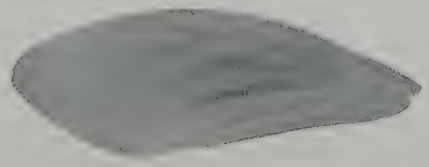


Fig.-85

EXPLANATION OF PLATES.

(All figures enlarged except figure 116, which is less than natural size.)

PLATE XXII.

External Anatomy of Tachytes distinctus.

FIG. 1.—Lateral view of thorax; *1*, prothorax; *2*, mesothorax; *3* metathorax; *4*, propodeum (first abdominal segment—median segment); *Cx*, coxa; *Epm*, epimeron; *Eps*, episternum; *It*, first abdominal segment; *L*, lateral lobe of pronotum; *N*, notum; *pl*, pleuron; *pn*, postnotum; *Scl*, scutellum; *Sct*, scutum; *Sp*, spiracle of first abdominal segment; *tg*, tegula; *2t*, basal portion of second abdominal segment.

FIG. 2.—Lateral view of abdomen; *2*, second abdominal segment; *7*, seventh abdominal segment; *pg*, pygidial area; *s*, sternum; *t*, tergum.

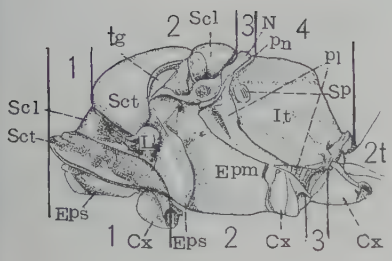
FIG. 3.—Dorsal view of thorax; symbols as in fig. 1; *AF*, apical fovea of propodeum; *F*, parapsidal furrow; *FW*, base of fore wing; *PF*, posterior sulcus of propodeum; *S*, socket of fore wing (the tegula being removed).

FIG. 4.—Ventral view of thorax; symbols as in fig. 1; *S*, sternum.

FIG. 5.—Hind leg, anterior lateral view; *Cx*, coxa; *f*, femur; *Tar*, tarsus; *tb*, tibia; *tr*, trochanter.

FIG. 6.—Anterior (front) view of head; *C*, clypeus; *f*, frons; *g*, glossa; *ia*, ocellar area; *l*, labrum; *m*, mandible; *mx*, maxilla; *p*, labial palpus; *Vx*, vertex.

PLATE XXII.



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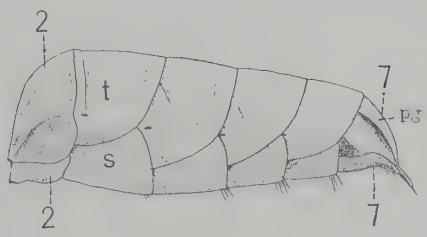

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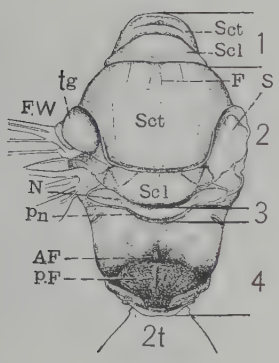

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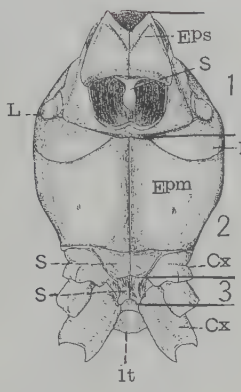

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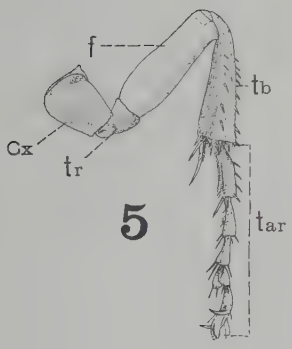

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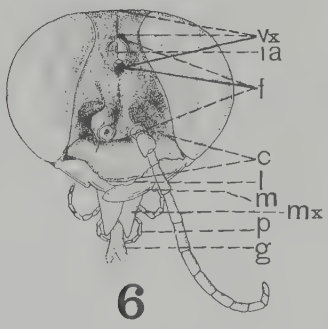

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PLATE XXIII.

Tachytes distinctus.

FIG. 7.—Ventral view of mouth parts; *C*, cardo (the paler inner half may represent the lorum); *d*, sclerite before labial palpus; *e*, sclerite before tip of mentum, connected with *d*; *f*, prong ("basal hooks of the glossa") of the ventral plate of the glossa; *GL*, glossa; *gr*, ventral apical furrow of ligula; *LP*, labial palpus; *M*, mentum; *MD*, base of mandible; *MP*, maxillary palpus; *MX* galea of maxilla; *O*, ventral portion of occiput; *PGL*, paraglossa; *SMT*, submentum; *ST*, stipe; *x*, ventral supporting plate of ligula.

FIG. 8.—Lateral view of mouth parts exclusive of maxillæ and mandibles; symbols as in fig. 7; *b*, passage to the blind sac *t*; *C*, clypeus; *D*, salivary duct; *EPH*, epipharynx; *g*, ventral plate of glossa; *h*, sclerite on under side of the plate or scale, *i*, of paraglossa; *k*, basal scale of ligula; *L*, labrum; *o*, passage to pharynx; *p*, anterior end or lobe of pharynx; *s*, "hypopharyngeal sclerite" (Sharp); *t*, pouch or blind sac.

FIG. 9.—Interior lateral view of maxilla; *C*, cardo; *L*, lacinia; *SMT*, submentum; *MX*, galea; *N*, less heavily chitinized inner portion of cardo, may be the lorum; *p*, base of palpus; *St*, stipe.

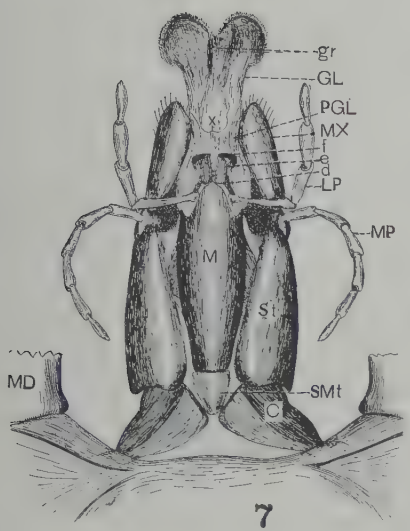
FIG. 10.—A nearly lateral view (ventral portion slightly inclined toward observer) of the mouth parts exclusive of the mandibles; symbols as in figs. 7 and 8; *n*, small sclerite under clypeus; *r*, "epipharyngeal sclerites" (Sharp) = pharyngeal rods.

FIG. 11.—Dorsal view of labium (slightly diagrammatic), to show the path followed by food as indicated by the arrows, lettering as in fig. 8; *A*, apical arrow, the beginning course for liquid food; *b*, second slope of ligula and passage to blind sac; *c*, lower edge of first slope to ligula; *so*, opening of salivary duct; *x*, first slope of ligula.

FIG. 12.—One of the hooks in the middle field of a series along the costal vein, *A*, of the second pair of wings.

FIG. 13.—Anterior view of fore coxæ of male, showing the coxal process, *H*; *tr*, trochanter.

PLATE XXIII.



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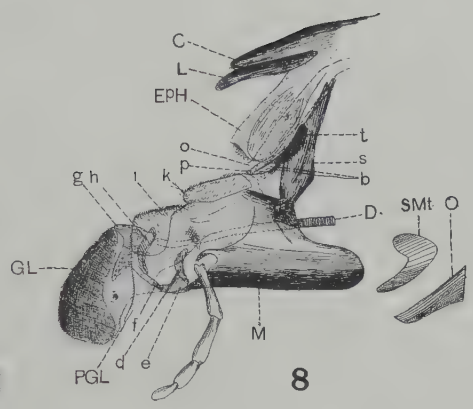

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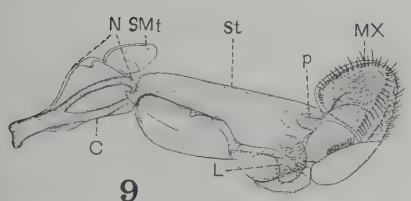

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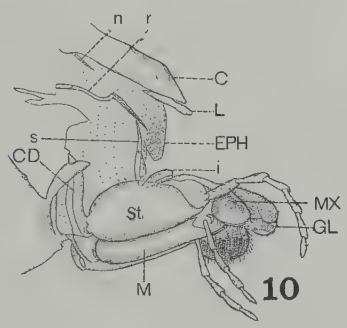

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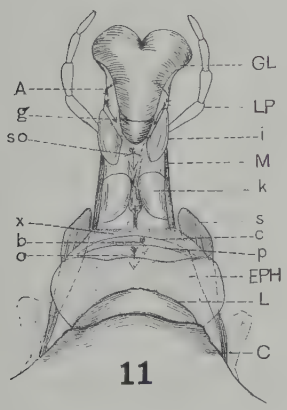

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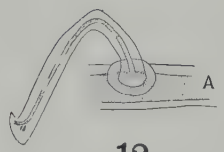

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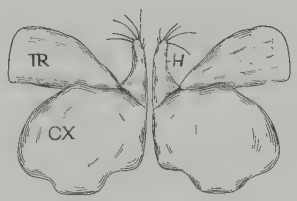

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PLATE XXIV.

FIG. 14.—Fore and hind wing of *Tachytes distinctus* ♀; the *veins* are named according to the system used by Cresson; lettering largely after Fernald (Chlorioninæ of N. A.); *a*, anal; *am*, apical margin; *ap*, appendiculate vein; *ax*, axillary; *b*, basal; *c*, costal; *cu*, cubital; *d*, discoidal; *ff*, frenal fold; *fh*, frenal hooks; *m*, median; *pm*, posterior margin; *r*, marginal or radial; re_1, first recurrent; re_2, second recurrent; *s*, stigma; *sc*, subcostal; *sd*, subdiscoidal; *si*, sinus; tc_1, first transverso-cubital; tc_2, second transverso-cubital; tc_3, third transverso-cubital; *tm*, transverse-median.

FIG. 15.—Fore and hind wing of *Tachysphex propinquus* ♀; the *cells* named according to the Cressonion nomenclature; lettering after Fernald; *a*, anal; ap_1, first apical; ap_2, second apical; *apd*, appendiculate cell; *c*, costal; cu_1, first cubital or submarginal; cu_2, second cubital or submarginal; cu_3, third cubital or submarginal; d_1, first discoidal; d_2, second discoidal; d_3, discoidal; *m*, median; *r*, radial or marginal; *sm*, submedian.

FIG. 16.—Wings of *Larra analis* ♀.

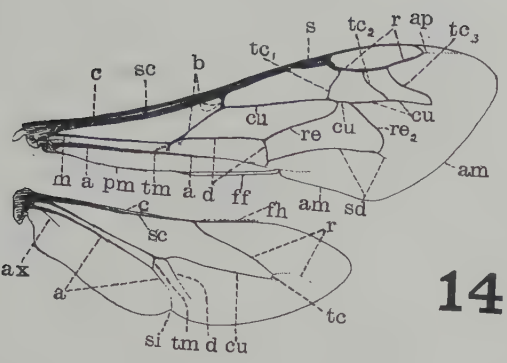
FIG. 17.—Wings of *Bothynostethus distinctus* ♂.

FIG. 18.—Wings of *Niteliopsis foxii* ♀ (type).

FIG. 19.—Wings of *Miscophus americanus* ♀.

FIG. 20.—Wings of *Plenoculus apicalis*.

PLATE XXIV.



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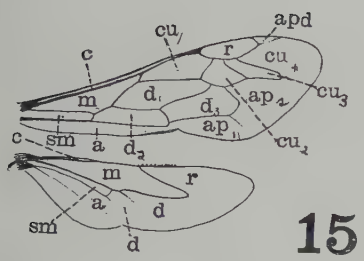

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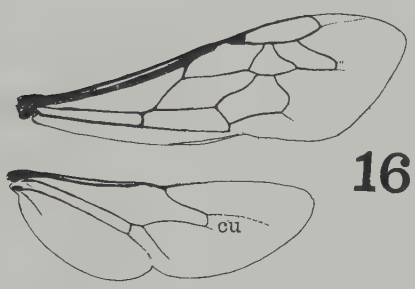

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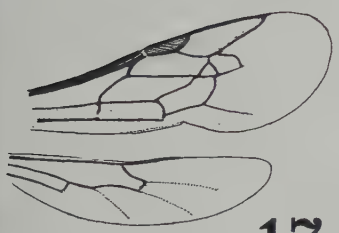

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PLATE XXV.

FIG. 21.—Mandible of *Tachytes distinctus*, showing the emargination.

FIG. 22.—Mandible of *Tachytes distinctus*, showing the two teeth within.

FIG. 23. Mandible of *Larropsis aurantia*.

FIG. 24.—Mandible of *Larra analis*, showing two indistinct teeth within.

FIG. 25.—Mandible of *Tachytes obscurus* ♀. Note that the stout mandible is quite narrowly emarginate.

FIG. 26.—Mandible of *Tachytes mergus*. Note its slenderness.

FIG. 27.—Mandible of *Tachysphex*, showing the deep and rather broad emargination.

FIG. 28.—Mandible of *Niteliopsis foxii* ♀ (type); *A*, lower margin.

FIG. 29.—Joints 2 to 4 of antenna of *Niteliopsis foxii* ♀ (type).

FIG. 30.—Antenna of *Niteliopsis inerme* ♂ ♀.

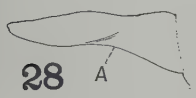
FIG. 31.—Joints 8 and 9 of antenna of *Tachysphex propinquus* ♂.

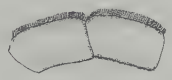
FIG. 32A.—Joints 2 to 4 of antenna of *Tachysphex terminatus* ♀.

FIG. 32B.—Joints 2 to 4 of antenna of *Tachysphex fusus* ♀.

FIG. 33.—Portion of the inner (posterior) margin of the fore wing of *Tachytes distinctus*, showing the fold or upturned edge, *F*, of the wing; *AN*, anal vein; *DN*, discoidal vein; *SDN*, subdiscoidal vein.

PLATE XXV.





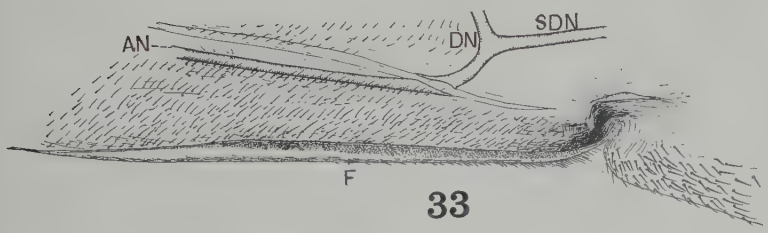


PLATE XXVI.

FIG. 34.—Ocellar area of *Notogonia argentata.* Note the small, nearly transverse posterior ocelli.

FIG. 35.—Ocellar area of *Tachysphex tarsatus.* The posterior ocelli are in a reniform or oblong area.

FIG. 36.—Ocellar area of *Larropsis aurantia.* Note the broad ocellar area.

FIG. 37.—Ocellar area of *Lyroda triloba.*

FIG. 38.—Ocellar area of *Plenoculus apicalis.*

FIG. 39.—Ocellar area of *Tachytes distinctus.* Note the long subparallel posterior ocelli and the rather narrow ocellar area.

FIG. 40.—Antenna of *Tachytes mandibularis* ♂, to show the convexity of the lower surface of joints 3 to 7.

FIG. 41.—Antenna of *Tachytes distinctus; b,* bulb of scape; *f,* flagellum; *p,* pedicel; *s,* scape.

FIG. 42.—Antenna of *Tachytes fulviventris* ♂, to show the broadened joints 9-11.

FIG. 43.—Antenna of *Plenoculus apicalis* ♂.

FIG. 44.—Basal portion of antenna of *Plenoculus apicalis* ♀.

FIG. 45.—Basal portion of antenna of *Plenoculus apicalis* ♂.

FIG. 46.—Tip of fore wing of *Larropsis pænerugosa* ♂ (type).

FIG. 47.—Tip of fore wing of *Tachysphex texanus* ♀.

FIG. 48.—Tip of fore wing of *Tachysphex acuta* ♀.

FIG. 49.—Lateral view of thorax of *Notogonia argentata,* showing the comparatively long propodeum.

FIG. 50.—Semidiagrammatic dorsal view of disc of propodeum of *Bothynostethus distinctus,* showing the character of sculpture.

FIG. 51.—Lateral view of thorax of *Larropsis,* showing the comparatively short propodeum.

PLATE XXVI.

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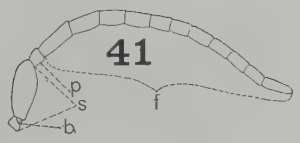

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PLATE XXVII.

FIG. 52.—Anterior margin of clypeus of *Tachytes mandibularis* ♂ ♀.

FIG. 53.—Anterior margin of clypeus of *Tachytes rufofasciatus* ♀.

FIG. 53A.—Anterior margin of clypeus of *Tachytes fulviventris* ♂.

FIG. 54.—Anterior margin of clypeus of *Tachytes obductus* ♀.

FIG. 55.—Anterior margin of clypeus of *Tachytes abdominalis* ♀.

FIG. 56.—Anterior margin of clypeus of *Tachytes validus* ♀.

FIG. 57.—Anterior margin of clypeus of *Tachytes distinctus* ♂ ♀.

FIG. 58.—Anterior margin of clypeus of *Tachytes obscurus* ♂.

FIG. 59.—Anterior margin of clypeus of *Tachytes pepticus* ♂ ♀.

FIG. 60.—Anterior margin of clypeus of *Tachytes sericatus* ♀.

FIG. 61.—Anterior margin of clypeus of *Tachytes mergus* ♀.

FIG. 62.—Anterior margin of clypeus of *Tachysphex tarsatus* ♂ ♀.

FIG. 63.—Anterior margin of clypeus of *Tachysphex terminatus* ♀.

FIG. 64.—Anterior margin of clypeus of *Tachysphex fusus* ♀.

FIG. 65.—Anterior margin of clypeus of *Tachysphex glabrior* ♂.

FIG. 66.—Anterior margin of clypeus of *Tachysphex belfragei* ♀.

FIG. 67.—Anterior margin of clypeus of *Tachysphex dentatus* (type) ♀.

FIG. 68.—Anterior margin of clypeus of *Tachysphex crenuloides* (type) ♀.

FIG. 69.—Anterior margin of clypeus of *Tachysphex clarconis* (type) ♀.

FIG. 70.—Anterior margin of clypeus of *Tachysphex propinquus* ♂.

FIG. 71.—Anterior margin of clypeus of *Tachysphex dubius* ♂.

FIG. 72.—Anterior margin of clypeus of *Tachysphex crassiformis* (type) ♀.

FIG. 73.—Anterior margin of clypeus of *Tachysphex propinquus* ♀.

FIG. 74.—Anterior margin of clypeus of *Bothynostethus distinctus* ♂.

FIG. 75.—Anterior margin of clypeus of *Miscophus americanus* ♀.

FIG. 76.—Anterior margin of clypeus of *Plenoculus apicalis* ♀.

FIG. 77.—Anterior margin of clypeus of *Plenoculus apicalis* ♂. Note the tuft of hair on either side.

PLATE XXVII.

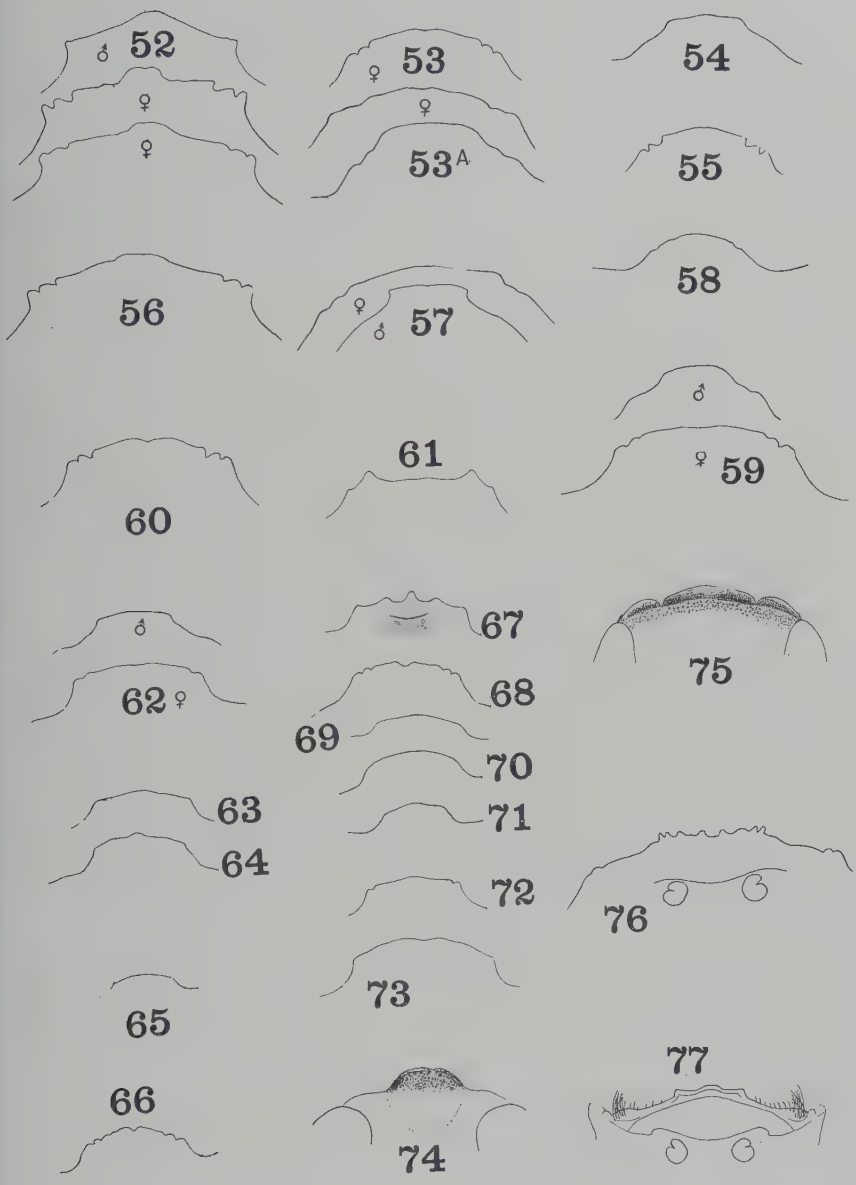
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PLATE XXVIII.

(Figs. 78-81 with the finer hairs omitted.)

FIG. 78.—Fore tarsus of *Larropsis* ♀, showing the fossorial comb of moderate bristles.

FIG. 79.—Fore tarsus of *Tachytes distinctus* ♂ ♀. The ♀ has the fossorial comb much better developed.

FIG. 80.—Fore tarsus of *Notogonia argentata* ♀. Note the weak comb; the insect works more often in heavy soil.

FIG. 81.—Fore tarsus of *Tachysphex propinquus* ♀. The long, flexible spines work to advantage in a sandy country.

FIG. 82.—Hind tibia of *Tachytes abdominalis* ♀, showing a row of stout, blunt thorns on outer side.

FIG. 83.—Ventral view of femur of *Tachytes distinctus* ♂, showing emargination.

FIG. 84.—Lateral view of fore femur of *Larropsis ater* ♂, showing emargination near base. Note the inner tooth; *tr*, trochanter.

FIG. 85.—Lateral view of portion of fore femur of *Tachytes distinctus* ♂.

FIG. 86.—Two views of hind femur of *Bothynostethus distinctus*, showing apical thickening.

FIG. 87.—Lateral view of fore femur of *Tachysphex tarsatus* ♂.

FIG. 88.—Antennal cleaner of *Notogonia argentata; tb*, tibia; *s*, modified spur; *tar*, tarsus with fringed emargination.

FIG. 89.—Antennal cleaner of *Astata* sp., one of the Nyssonidæ, showing the furcation of the modified tibial spur, a character not found in the Larridæ.

PLATE XXVIII.

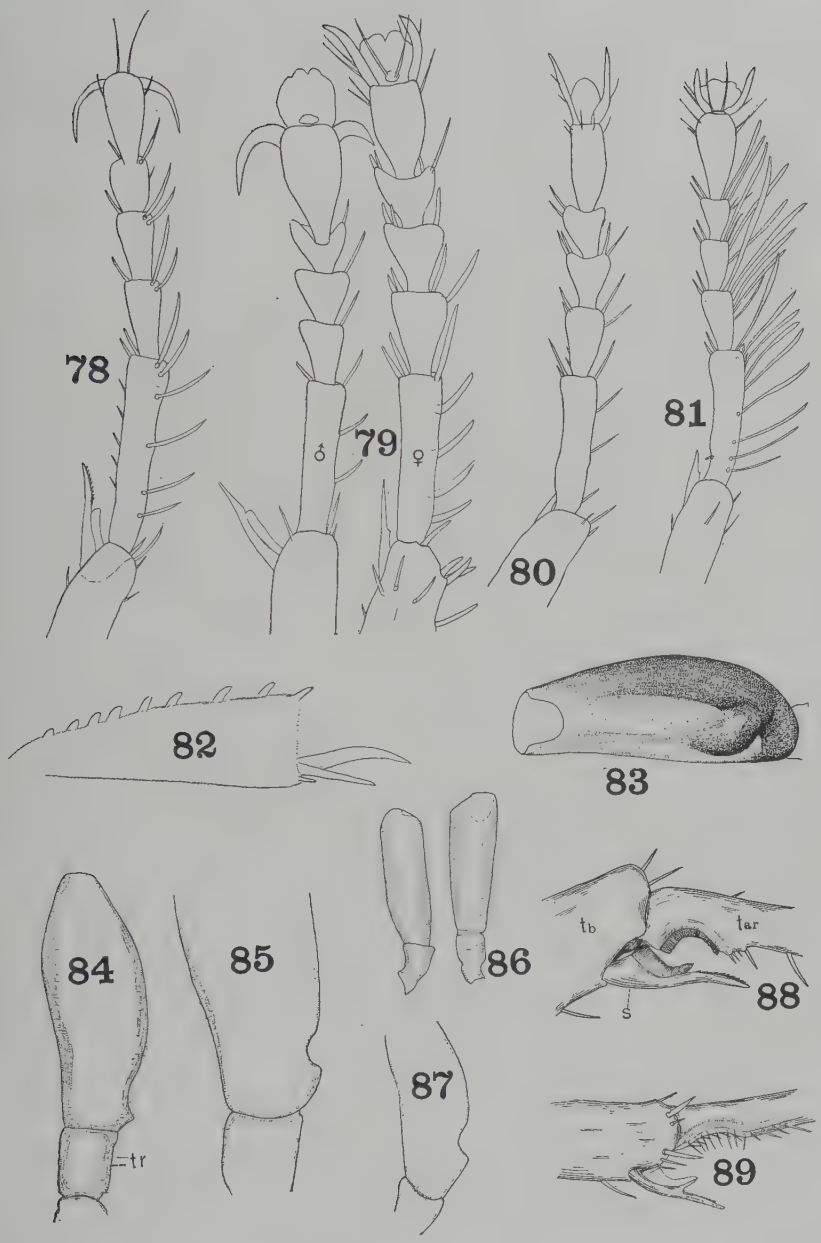

PLATE XXIX.

FIG. 90.—Pygidium of *Tachytes mandibularis* ♀.

FIG. 91.—Pygidium of *Tachytes obductus* ♀.

FIG. 92.—Pygidium of *Tachytes distinctus* ♀.

FIG. 93.—Pyigdium of *Tachytes mergus* ♀.

FIG. 94.—Pygidium of *Tachytes distinctus* ♀.

FIG. 95.—Pygidium of *Bothynostethus distinctus* ♂.

FIG. 96.—Pygidium of *Lyroda subita* ♀.

FIG. 97.—Pygidium of *Notogonia argentata* ♀.

FIG. 98.—Pygidium of *Niteliopsis foxii* ♀ (type). The area has no bounding carinæ.

FIG. 99.—Pygidium of *Larropsis divisa* ♀.

FIG. 100.—Eighth ventral plate of *Larropsis ater* ♂.

FIG. 101.—Eighth ventral plate of *Larropsis bruneri* ♂.

FIG. 102.—Pygidium of *Plenoculus apicalis* ♀.

FIG. 103.—Dorsal view of end of abdomen of *Plenoculus apicalis* ♂, showing eighth ventral segment.

FIG. 104.—Pygidium of *Tachysphex propinquus* ♀.

FIG. 105.—Pygidium of *Tachysphex crenuloides* ♀ (cotype).

FIG. 106.—Pygidium of *Tachysphex dentatus* ♀ (type).

FIG. 107.—Pygidium of *Larra analis* ♀.

FIG. 108.—Apical portion of eighth ventral plate of *Tachytes mandibularis* ♂.

FIG. 109.—Apical portion of eighth ventral plate of *Tachytes pepticus* ♂.

FIG. 110.—Apical portion of eighth ventral plate of *Tachytes fulviventris* ♂.

FIG. 111.—Apical portion of eighth ventral plate of *Tachytes distinctus* ♂.

PLATE XXIX.

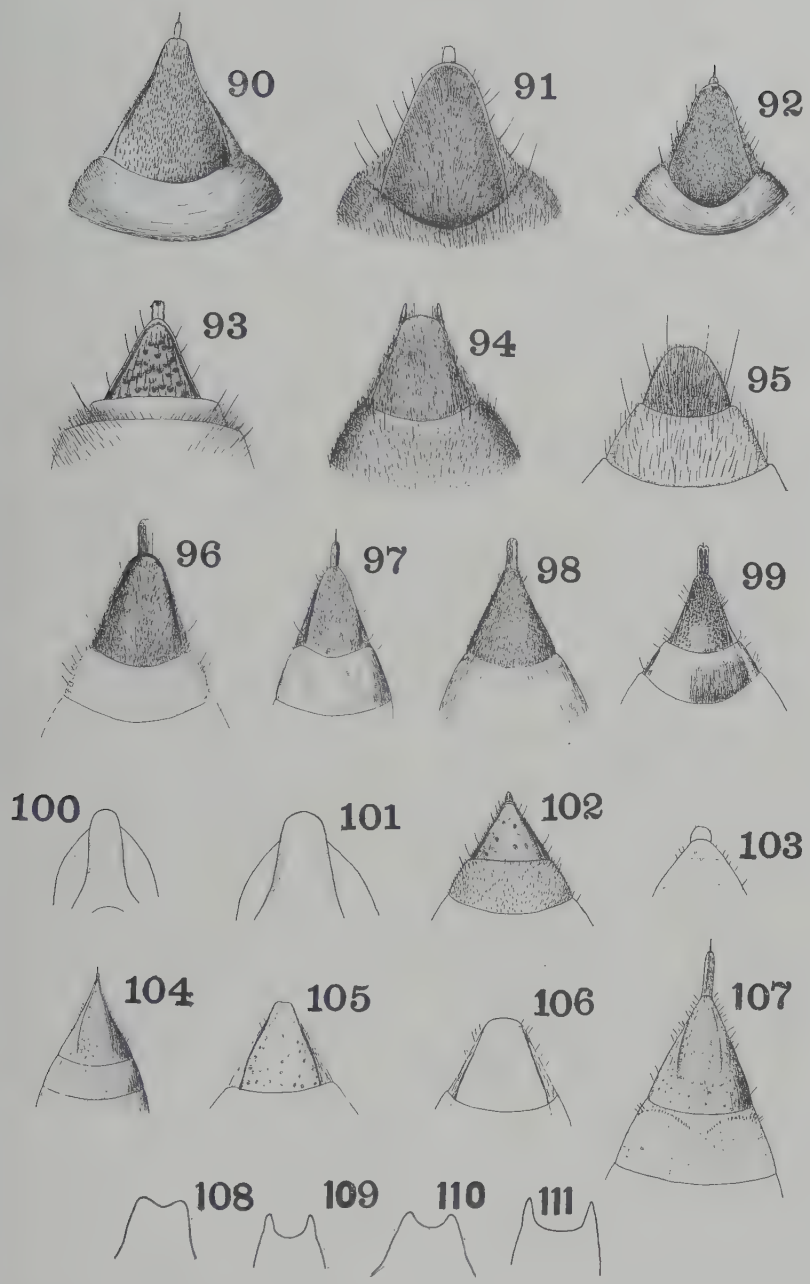
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PLATE XXX.

FIG. 112.—*Tachysphex propinquus* ♀, dragging the locust *Mestobregma kiowa* ♂ to her nest. Grant county, Kansas, August, 1911. The wasp seizes the locust's antennæ with her mandibles and holds the body of her prey with her posterior pair of legs, using the four anterior ones in traveling.

FIG. 113.—Egg of *Tachytes distinctus*. The cephalic end is the more enlarged one, toward the middle of the page.

FIG. 114.—Front and anterior ventral view of a full-grown larva of *Tachytes distinctus*. Rooks county, Kansas, August, 1912.

FIG. 115.—Lateral view of a half-grown larva of *Tachytes distinctus*.

FIG. 116.—Entrance to nest of *Tachytes distinctus*. Rooks county, Kansas, August, 1912.

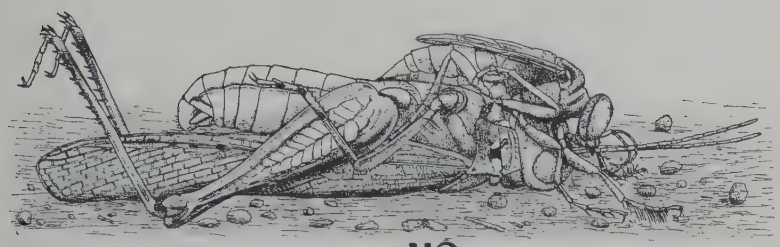
FIG. 117.—Ventral aspect of young Œdipodinæ, showing egg, *E*, of *Tachysphex tarsatus* transversely arranged on prosternum, where it is secured behind the left coxa. Rooks county, Kansas, August, 1912.

FIG. 118.—Ventral aspect of head and thorax of young cricket (*Gryllus*), showing the egg, *E*, of *Notogonia argentata*, secured on inner side and at the base of the left anterior coxa. Lawrence, Kansas, September, 1911.

FIG. 119.—Ventral aspect of young hemipterous insect (Capsidæ), showing the egg, *E*, of *Niteliopsis inerme* transversely arranged behind the fore legs and secured behind the right coxa. Ellis county, Kansas, July, 1912.

FIG. 120.—Ventral aspect of a young hemipterous insect (*Atomoscelis*, fam. Capsidæ) showing a young *Plenoculus apicalis* larva feeding on same.

PLATE XXX.



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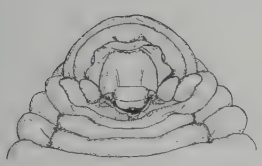

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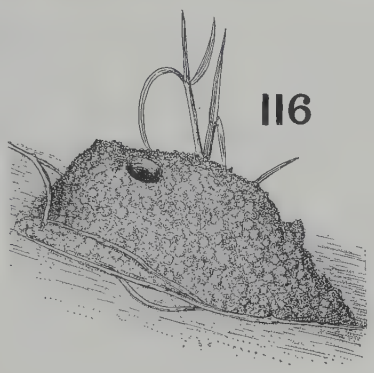

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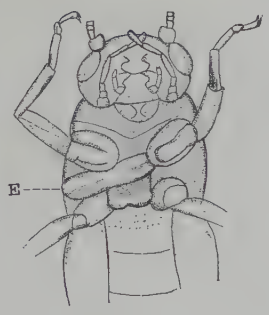

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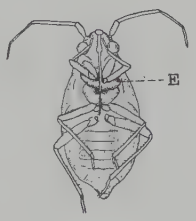

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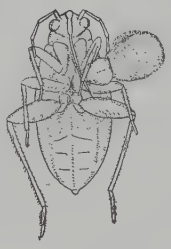

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PLATE XXXI.

Fig. 1.—Adult *Melittia snowi* ♀ (alar expanse, 23 mm.).

Fig. 2.—Mature larva of *Melittia snowi* (length, 26 mm.).

Fig. 3.—Cocoon of *Melittia snowi* (length, 17 mm.).

Fig. 4.—Egg of *Melittia snowi* (length, about .8 mm.).

Fig. 5.—Pupal shell of *Melittia snowi* (length, 18 mm.).

Fig. 6.—Pupal shell of *Melittia gloriosa* ♀ (length, 47 mm.).

PLATE XXXI.

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PLATE XXXII.

Fig. 7.—Galls on *Cucurbita fœtidissima,* made by the larva of *Melittia snowi.*

Fig. 8.—A gall formed from a tendril stem.

Length of shoot (fig. 7), 240 mm.

PLATE XXXII.

PLATE XXXIII.

FIG. 1.—*Mimesa argentifrons* ♀ (× 3.8).

FIG. 2.—Burrow of *Prionopyx atrata* ♀. Cell contains the locust, *Aulocara elliotti*. About natural size.

FIG. 3.—*Athysanus exitiosa*, the prey of *Mimesa argentifrons* (× 3.8).

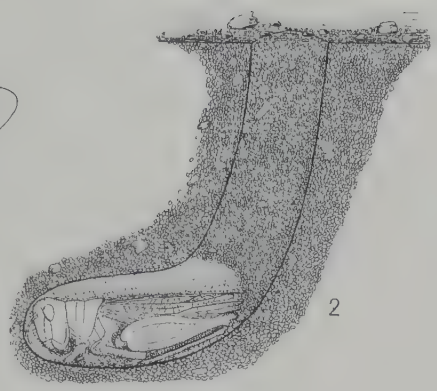
FIG. 4.—*Harpactus gyponæ* ♀ (× 3.8).

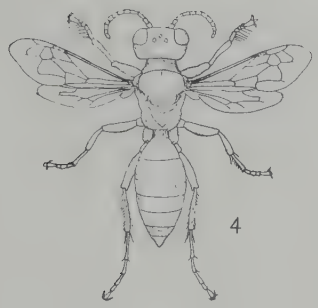
FIG. 5.—*Gypona cinerea*, the prey of *Harpactus gyponæ* (× 3.8).

FIG. 6.—Dorsal view of *Melanoplus lakinus* ♀, showing egg (*E*) of *Prionopyx atrata* (× 1.6).

FIG. 7.—*Prionopyx atrata* ♀ (× 1.6).

PLATE XXXIII.





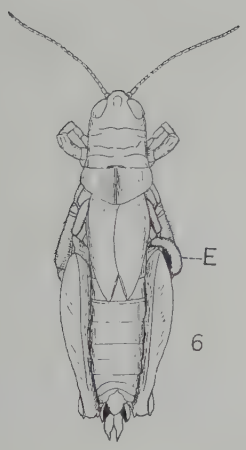


PLATE XXXIV.

FIG. 1.—Vertical section of a nest of *Pt. 5-faciatus;* eggs suspended in cells.

FIGS. 2, 3 AND 4.—Vertical sections of nests of *O. dorsalis,* opening in level ground; eggs suspended in some cells.

FIG. 5.—Vertical section of nest of *O. dorsalis,* opening in face of bank.

FIGS. 6 AND 7.—Vertical sections of nests of *O. arvensis;* tube over entrance.

FIG. 8.—Nest of *Eumenes* on a rock.

FIGS. 9 AND 10.—Nests of *E. bolli.*

FIG. 11.—Earthen bank inhabited by *O. hildagi* and by a colony of *O. papagorum.* Photo by F. X. Williams.

PLATE XXXIV.

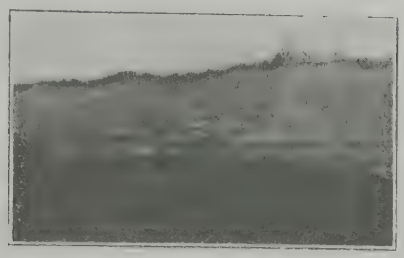


Fig. 11.

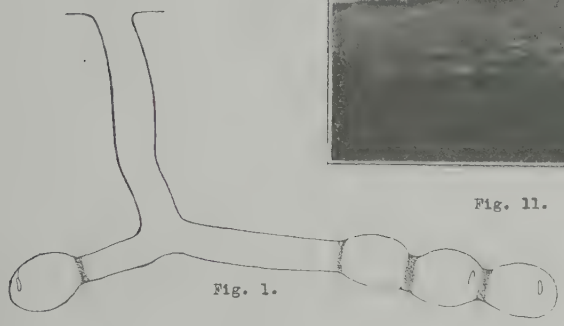


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 7.

Fig. 8.

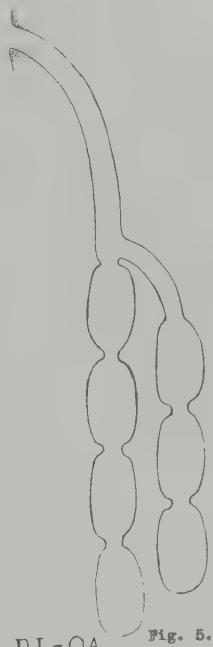


Fig. 5.

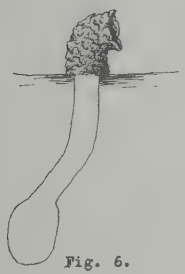


Fig. 6.

Fig. 9.

Fig. 10.

D.I.-O.A.

PLATE XXXV.

FIG. 12.—Vertical section of nest of *O. hildagi.*

FIG. 13.—Cell of nest of *O. hildagi.*

FIG. 14.—Vertical section of nest of *O. annulatus*; tube over entrance.

FIG. 15.—Vertical section of nest of *O. annulatus*; all parts brought into one plane; tube removed.

FIG. 16.—Tube over entrance to nest shown in figure 15.

FIG. 17.—Tube extending from bank over entrance of nest of *O. papagorum.*

FIGS. 18 AND 19.—Horizontal sections of burrows of *O. papagorum,* showing arrangement of entrances of cells and galeries into main burrow.

FIGS. 20 AND 22.—Vertical sections of nests of *O. papagorum,* with tubes over entrance.

FIG. 21.—Vertical section of lower part of a nest of *O. papagorum;* eggs in cells.

FIG. 23.—Nest of *E. fraternus.*

PLATE XXXV.

Fig. 12.

Fig. 14.

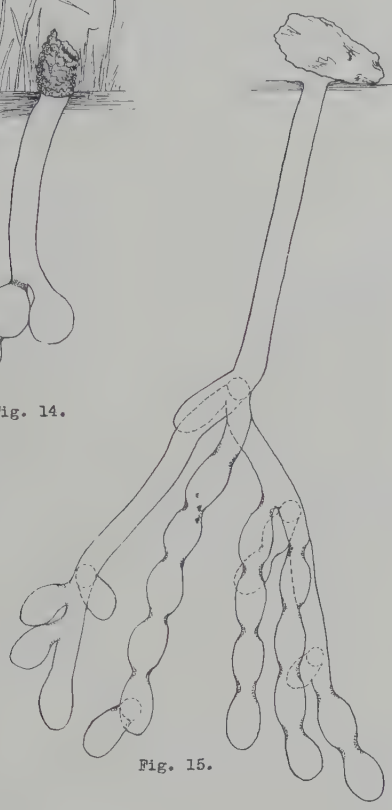


Fig. 15.

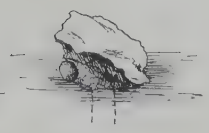


Fig. 16.

Fig. 17.

Fig. 13.

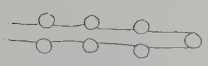


Fig. 18.

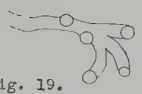


Fig. 19.

Fig. 23.

Fig. 20.

Fig. 21.

Fig. 22.

D.I.-O.A.

PLATE XXXVI.

FIG. 24.—*O. papagorum.*

FIG. 25.—*O. arvensis.*

PLATE XXXVI.

Fig. 24.

Fig. 25.

PLATE XXXVII.

FIG. 26.—*E. bolli.*

FIG. 27.—*Pt. 5-faciatus.*

PLATE XXXVII.

Fig. 26.

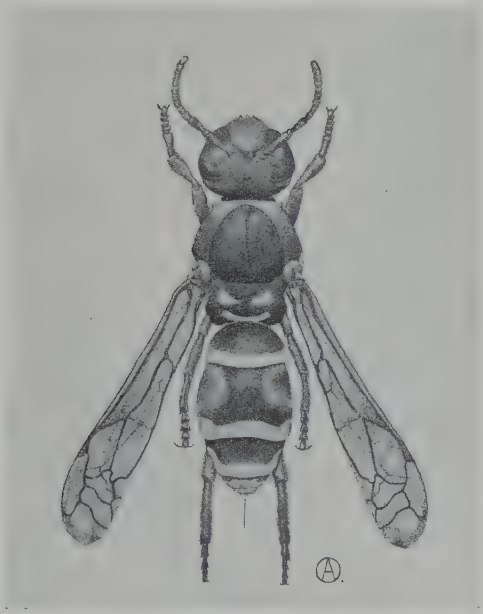


Fig. 27.

PLATE XXXVIII.

FIG. 1. Typical breeding place of *Simulium vittatum*, Turkey creek, Oswego, Kan.

FIG. 2. Pupæ on the under side of a stone, from ripples in the stream shown in figure 1. (Slightly reduced.)

FIG. 3. A *Simulium* fly trap in a ripple, showing the method of catching the flies as they emerge. When removing the flies from the trap a black cloth is put around the white cone over which Prof. S. J. Hunter is holding a glass bottle for the flies to emerge into.

PLATE XXXVIII.

Fig. 1

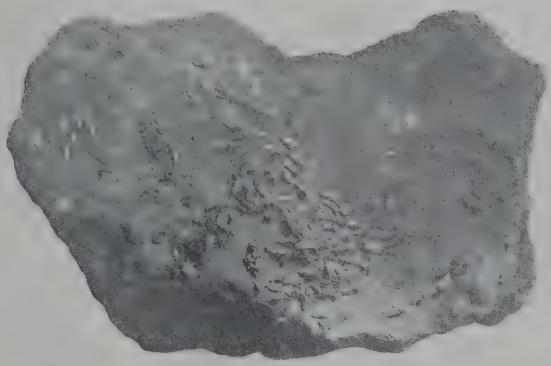


Fig. 2

Fig. 3

PLATE XXXIX.

FIG. 5. Female *S. vittatum.* (Greatly enlarged).

FIG. 6. Male *S. vittatum.* (Greatly enlarged).

FIG. 7. Dorsal view of Simulium pupa removed from pupa case, showing pupal breathing gills and development of wing pads.

FIG. 8. *Simulium* pupa immediately after transforming from the larval state, showing the immature development of wing pads.

FIG. 9. Lateral view of pupa, showing the membrane which holds it in the pupa case.

FIG. 10. Adult *Simulium* larva.

FIG. 11. Adult *Simulium* larvæ, showing the proleg at *P* and the caudal aperture at *A*. (See plate XVI, figure 34, *A*.)

FIG. 12. *Similium* egg highly magnified.

FIG. 13. Mass of *Similium* eggs magnified.

FIG. 21. Mandibles and part of clypeus.

FIG. 23. Labrum and hypopharynx united. *A* and *B*, points of attachment; *H*, hypopharynx; *L*, labrum.

FIG. 25. Wing of *S. vattatum.*

PLATE XXXIX.

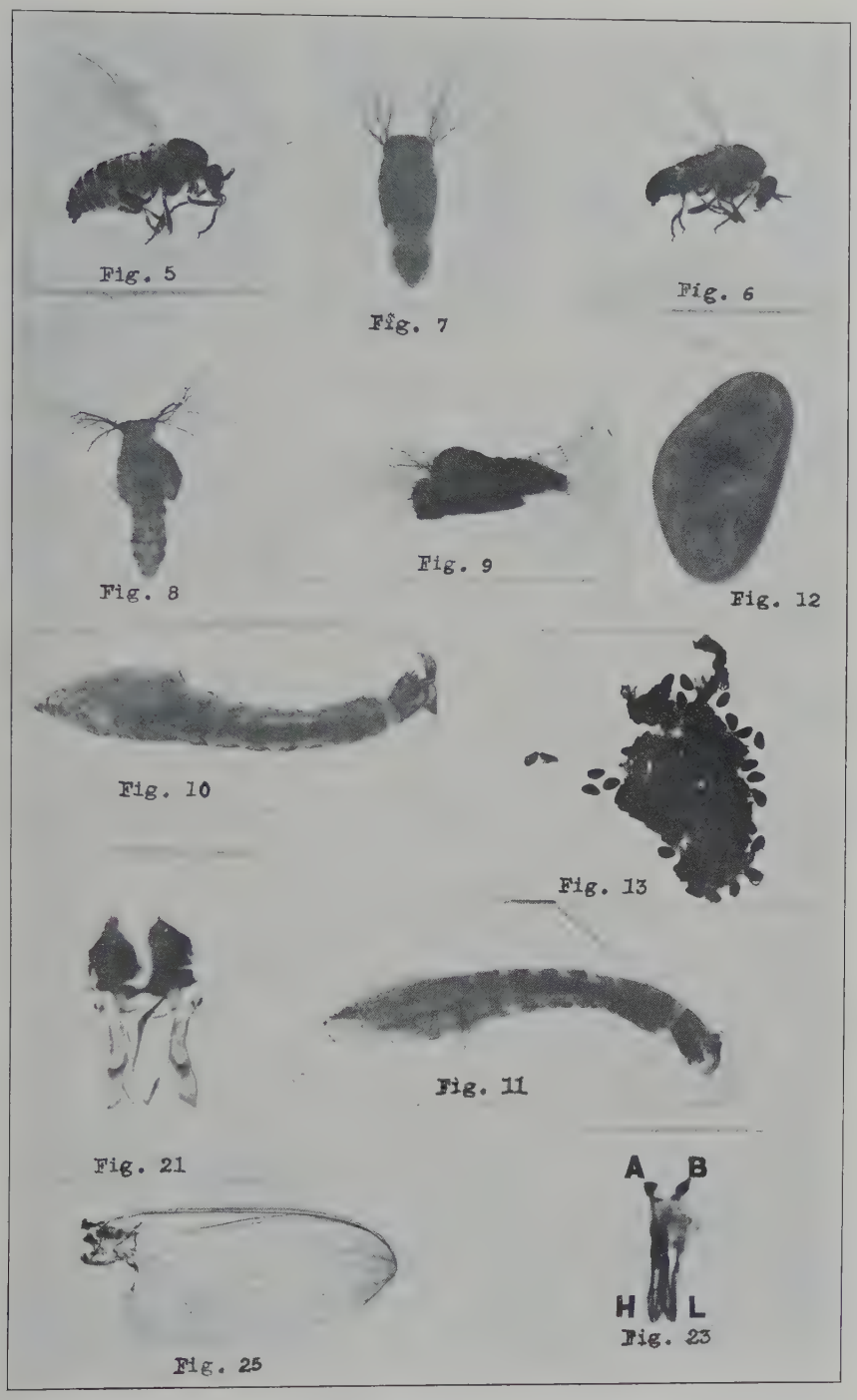


Fig. 5
Fig. 7
Fig. 6
Fig. 8
Fig. 9
Fig. 12
Fig. 10
Fig. 13
Fig. 11
Fig. 21
A
B
H
L
Fig. 23
Fig. 25

PLATE XL.

FIG. 14. Composite view of head and mouth parts of *Simulium vittatum*. *E*, eyes; *C*, clypeus; *MD*, mandible; *MX*, maxilla; *LA*, labrum; *ooo*, muscular attachments of labrum and clypeus; *LM*, labium; *HPY*, hypopharynx; *oo*, attachments of hypopharynx and labrum.

FIG. 15. Lacina of maxilla, greatly enlarged, showing the barb-like teeth turned backward on it.

FIG. 16. End of labrum, showing the chitinized parts and the two teeth.

FIG. 17. Maxilla of *S. vittatum*. *C*, cardo; *S*, stipes; *PF*, palpifer; *L*, lacina; *PA*, palpus.

FIG. 18. End of mandible, greatly enlarged to show the saw-like teeth on its end.

FIG. 19. Antennæ of *S. vittatum*.

FIG. 20. *C*, clypeus; *M*, mandibles.

FIG. 22. Mandible. *C*, condyle (?) of mandible.

FIG. 24. *A′ B′*, points of hypopharynx where *A* and *B* of the labrum attach.

PLATE XL.

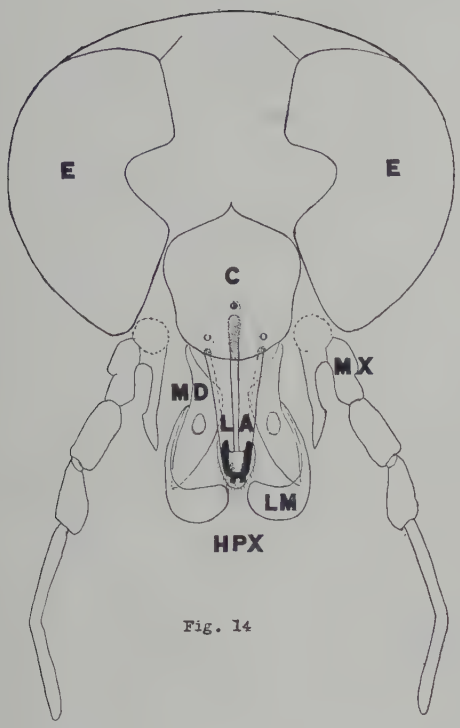


Fig. 14

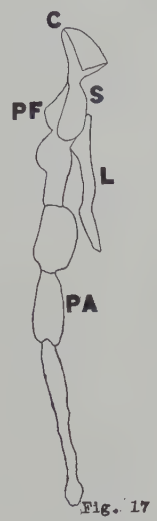


Fig. 17

Fig. 15

Fig. 22

Fig. 24

Fig. 20

Fig. 18

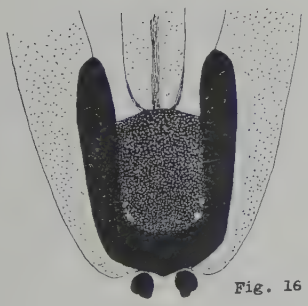


Fig. 16

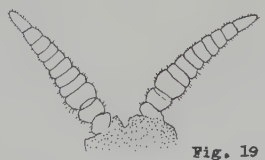


Fig. 19

PLATE XLI.

FIG. 26. Composite view of head of a female *S. vittatum.* (All photographs of the fly except the one of the pupæ on the stone are greatly enlarged views of the specimens.

FIG. 27. Hypopharynx and maxilla of *S. vittatum.*

FIG. 28. Composite view of mouth parts, showing all the parts intact except the labium, which is entirely removed. The hypopharynx is turned under and upward in the photograph.

FIG. 29. Male *S. vittatum* mouth parts. Note the tip of the labrum has the two teeth coalesced. Note the difference in the size of the facets of the eye.

FIG. 30. Labium of female. All mouth parts figured are of the female except figure 28. *G,* glossa; *PG,* paraglossa; *M,* mentum.

FIG. 31. Ventral view of head of *Simulium* larva, showing the fan-like organs spread out.

FIG. 32. *MD,* mandible of *Simulium* larva; *AT,* antennæ of *Simulium* larva. (According to Johannsen.)

FIG. 33. Maxilla of *Simulium* larva, showing the palpus at *P.*

FIG. 34. Labium of *Simulium* larva.

FIG. 35. *LA,* labrum of *Simulium* larva; *HY,* hypopharynx of *Simulium* larva; *A,* anal aperture of *Simulium* larva. The U-shaped part lies dorso-cephalad to the rest of it in the larva. Note the rasp-like formation of this organ. The larva uses it to hold onto the stones in the ripples.

PLATE XLI.

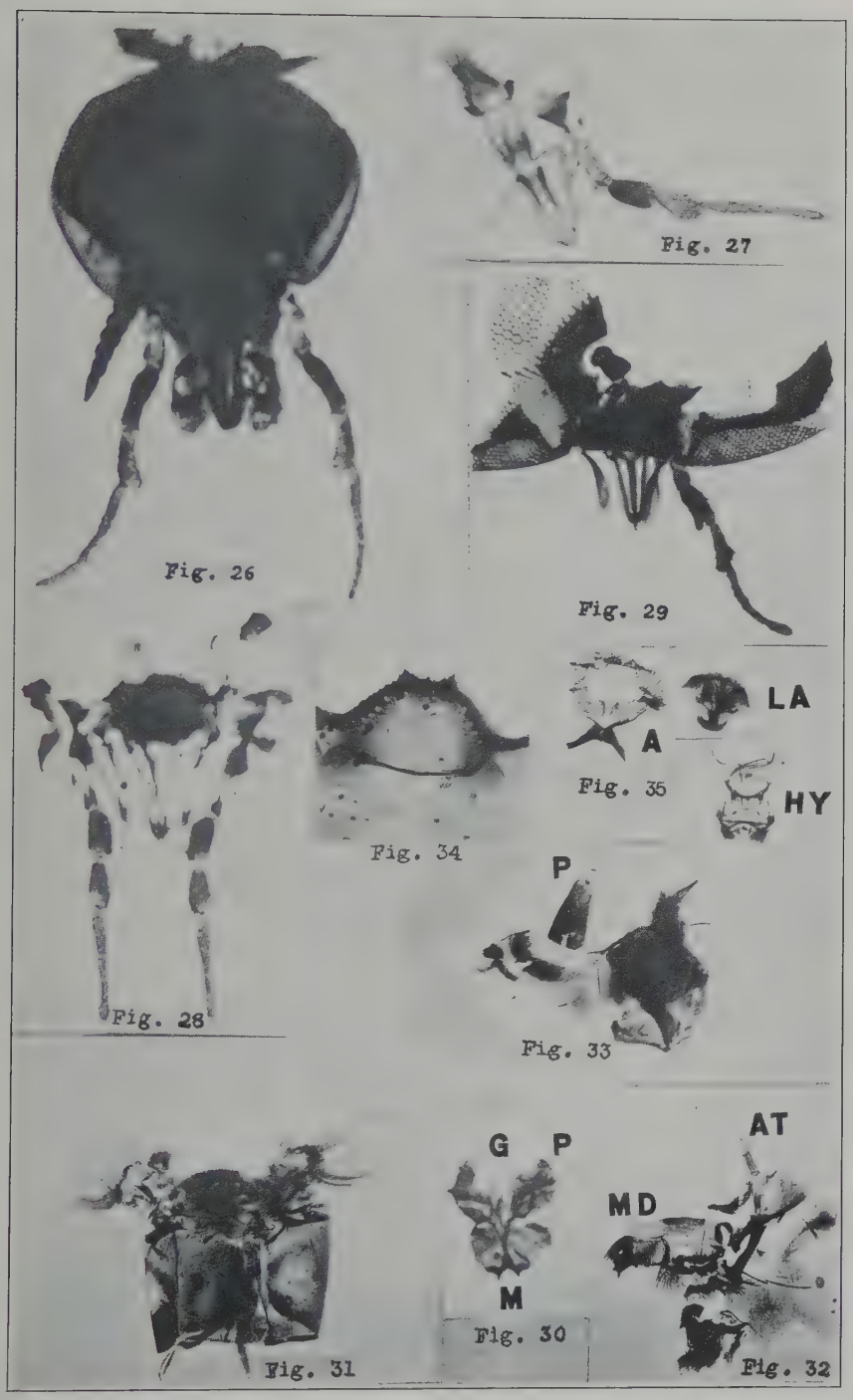


Fig. 26
Fig. 27
Fig. 29
Fig. 28
Fig. 34
A
LA
Fig. 35
HY
P
Fig. 33
G
P
M
Fig. 30
Fig. 31
AT
MD
Fig. 32

PLATE XLII.

Map of Kansas, showing the location and distribution of *Simulium* flies. A complete survey of Kansas for *Simulium* has not been made, but the survey that has been made to date as shown by the map would indicate that *Simulium* flies are generally distributed over the state where there are year-round flowing streams of water. *S*, location of *Simulium*.

PLATE XLII.

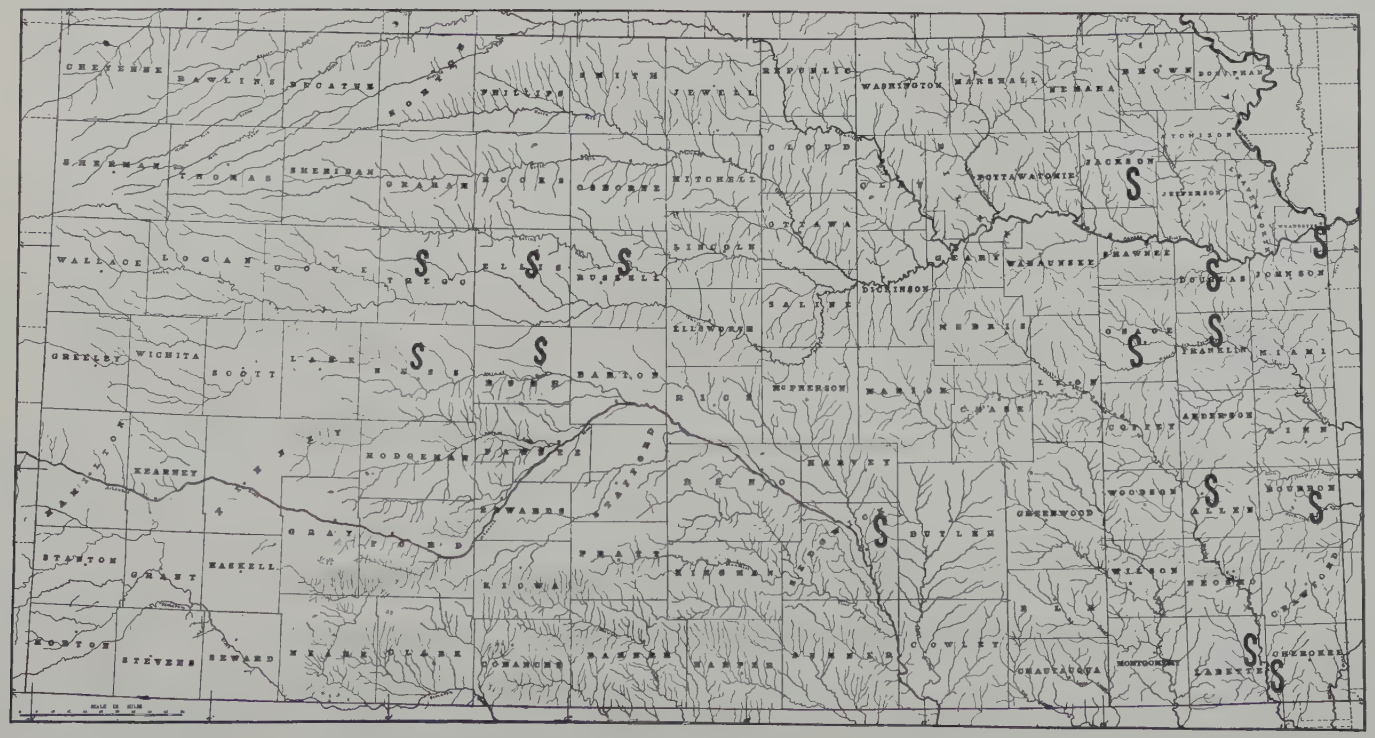

CHEYENNE
RAWLINS
DECATUR
NORTON
PHILLIPS
SMITH
JEWELL
REPUBLIC
WASHINGTON
MARSHALL
NEMAHA
BROWN
DONIPHAN
SHERMAN
THOMAS
SHERIDAN
GRAHAM
ROOKS
OSBORNE
MITCHELL
CLOUD
CLAY
POTTAWATOMIE
JACKSON
ATCHISON
JEFFERSON
WALLACE
LOGAN
GOVE
TREGO
ELLIS
RUSSELL
LINCOLN
OTTAWA
DICKINSON
GEARY
WABAUNSEE
SHAWNEE
DOUGLAS
JOHNSON
GREELEY
WICHITA
SCOTT
LANE
NESS
RUSH
BARTON
ELLSWORTH
SALINE
MORRIS
OSAGE
FRANKLIN
MIAMI
RICE
MCPHERSON
MARION
CHASE
LYON
COFFEY
ANDERSON
LINN
KEARNEY
HODGEMAN
PAWNEE
STAFFORD
HARVEY
WOODSON
BOURBON
ALLEN
STANTON
GRANT
HASKELL
GRAY
EDWARDS
PRATT
KIOWA
KINGMAN
BUTLER
GREENWOOD
WILSON
NEOSHO
MORTON
STEVENS
SEWARD
MEADE
CLARK
COMANCHE
BARBER
PRATT
HARPER
SUMNER
COWLEY
CHAUTAUQUA
MONTGOMERY
LABETTE
CHEROKEE

PLATE XLIII.

FIG. 1.

Lateral view of female fly.

Pn—Pronotum.
n—Notum of mesothorax.
ms—mesothoracic spiracle.
m′s—metathoracic spiracle.
m″s—mesosternum.
as—abdominal spiracles.
tr—tarsi.
c—costa.
sc—subcosta.
e—emargination marking junction of r with costa.
r—radius.
r+—radius 2+3+4+5.
m+m′—media 1 and 2.
cn—cupitus.
a—anal veins.

FIG. 2.

Dissection study of fly from left side.

In the thorax the oblique muscles have been removed to show the left longitudinal thoracic muscle in place but shrunken—the trachea, t, is shown also in figure 5 as dotted. A portion of the metathoracic integument (in) is left intact to show metathoracic spiracle.

s—stomach.
mp—Malpighian tubules of left side shown.
h—dorsal vessel.
rp—rectal pouch also shown in fig. 3.
i—chitinized invagination.
th—muscle of thorax.

FIG. 3.

Rectal pouch showing striations and three of the papillæ—rp. These show the nuclei, having been stained with borax carmine.

FIG. 4.

Salivary glands.

d—common duct leading to salivary receptacle.
r—reservoir.
g—gland showing nuclei—from a stained specimen.

PLATE XLIII.

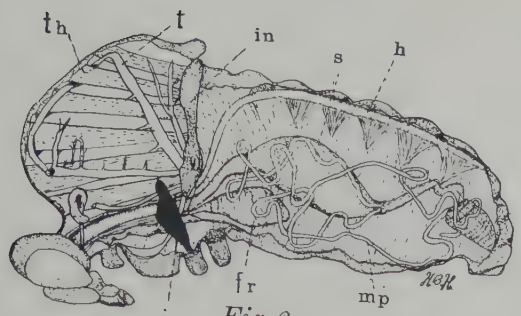


Fig. 2

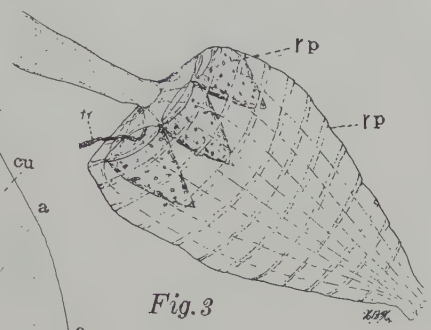


Fig. 3

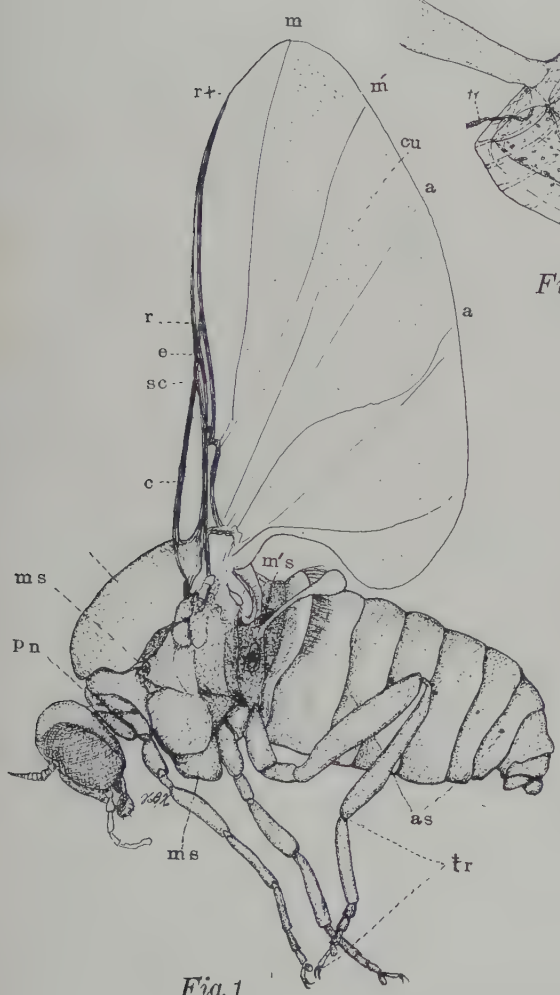


Fig. 1

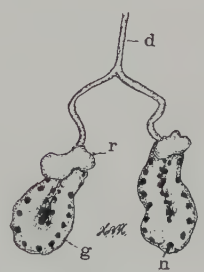


Fig. 4

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PLATE XLIV.

FIG. 5.

Integument of left side removed to show tracheal system. Trachea dotted in—not visible from surface view. Portions of integument left to support the meso- and meta-thoracic spiracles.

ms—mesothoracic spiracle.
m's—metathoracic spiracle.
in—integument of meta thorax.
tr—trachea.
mt—main trunk of trachea in thorax.

FIG. 6.

Reproductive and nervous systems.

ov—ovary (left).
s—salivary gland (left).
nc—nerve cord.
st—spermatheca.
c—chitinized invagination.

FIG 7.

Female genital apparatus—view from above.

st—spermatheca.
cr—chitinized rod.
ag—accessory glands.
rp—rectal pouch.
n—muscular attachment of chitinized rod.

FIG. 8.

v—terminal valves.
go—genital pore.
r—attachment of cephalic end of the chitinized rod shown in figure 7. The black line shows the arch of the chitinized rod.

FIG. 9.

Ventral view of abdomen of female showing fat body and ovaries in position.

F—fat body.
n—Malpighian tubule.
ov—ovary.
sp—spermatheca.
a—anus.

PLATE XLIV.

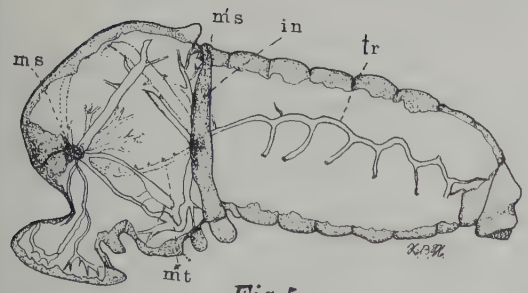

Fig. 5

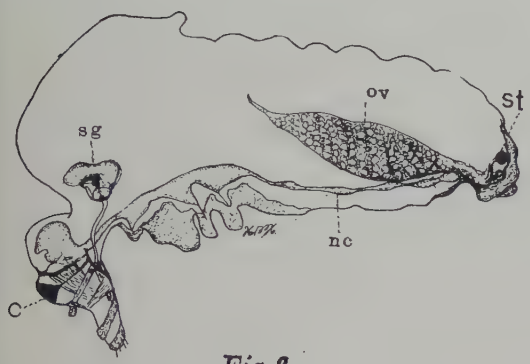

Fig. 6

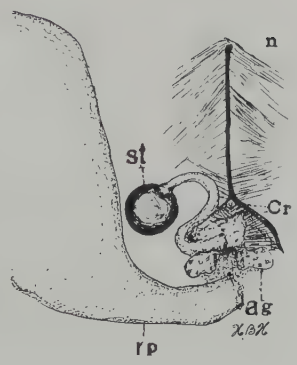

Fig. 7

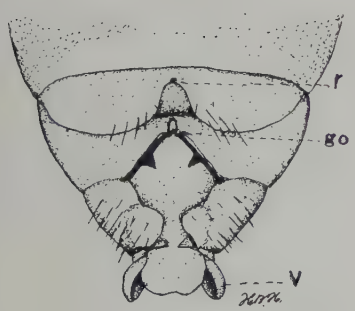

Fig. 8

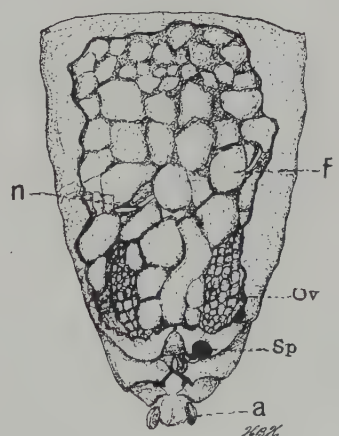

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PLATE XLV.

FIG. 10.

Sketch showing attachment of maxilla to chitinized brace of head.

FIG. 11.

Head and food reservoir.

c—chitinized color.
Ph—pharynx.
sy—salivary receptacle.
œ—œsophagus.
Per—proventriculus.
Fr—food reservoir.

FIG. 12.

Projection drawing of a microtome section of head.

tm—thoracic muscle.
br—brain.
roe—œsophageal muscle.
Phy—muscles of pharynx.
lm—muscles of labrum.
sr—salivary reservoir.
Ph—pharynx.
g—œsophageal ganglion.
lr—labrum.

PLATE XLV.

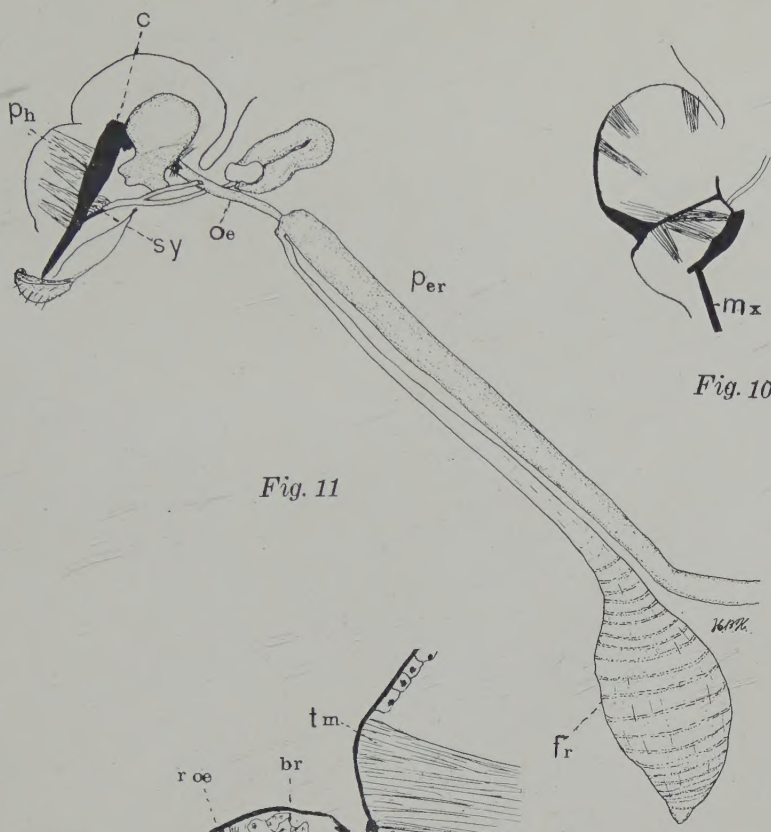

Fig. 11

Fig. 10

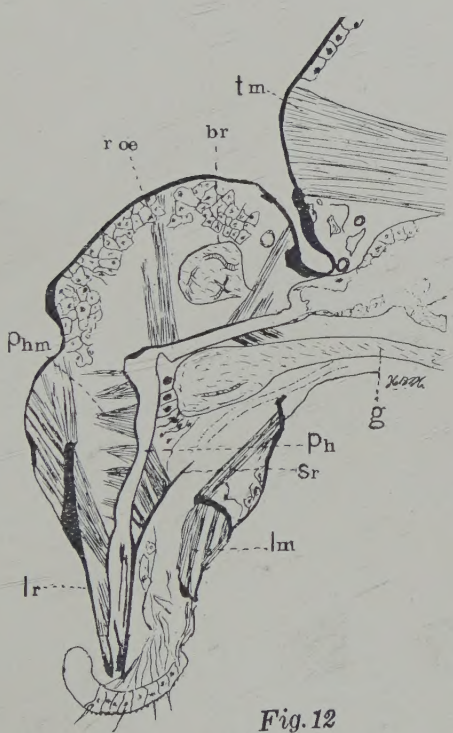

Fig. 12

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